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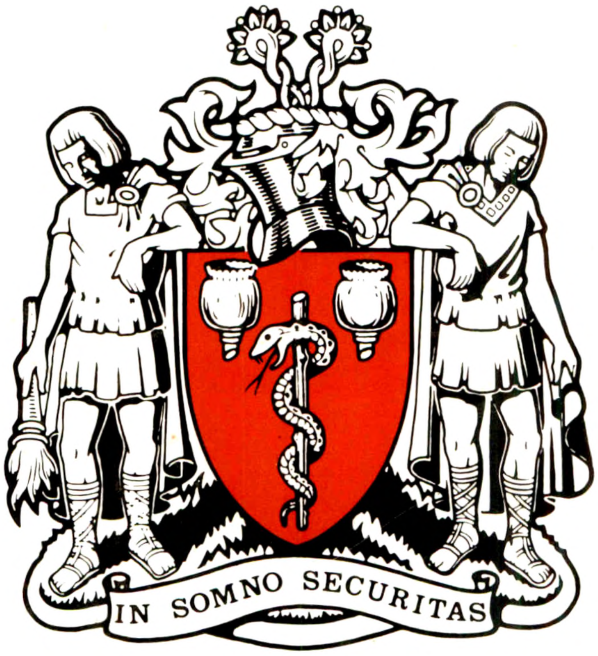

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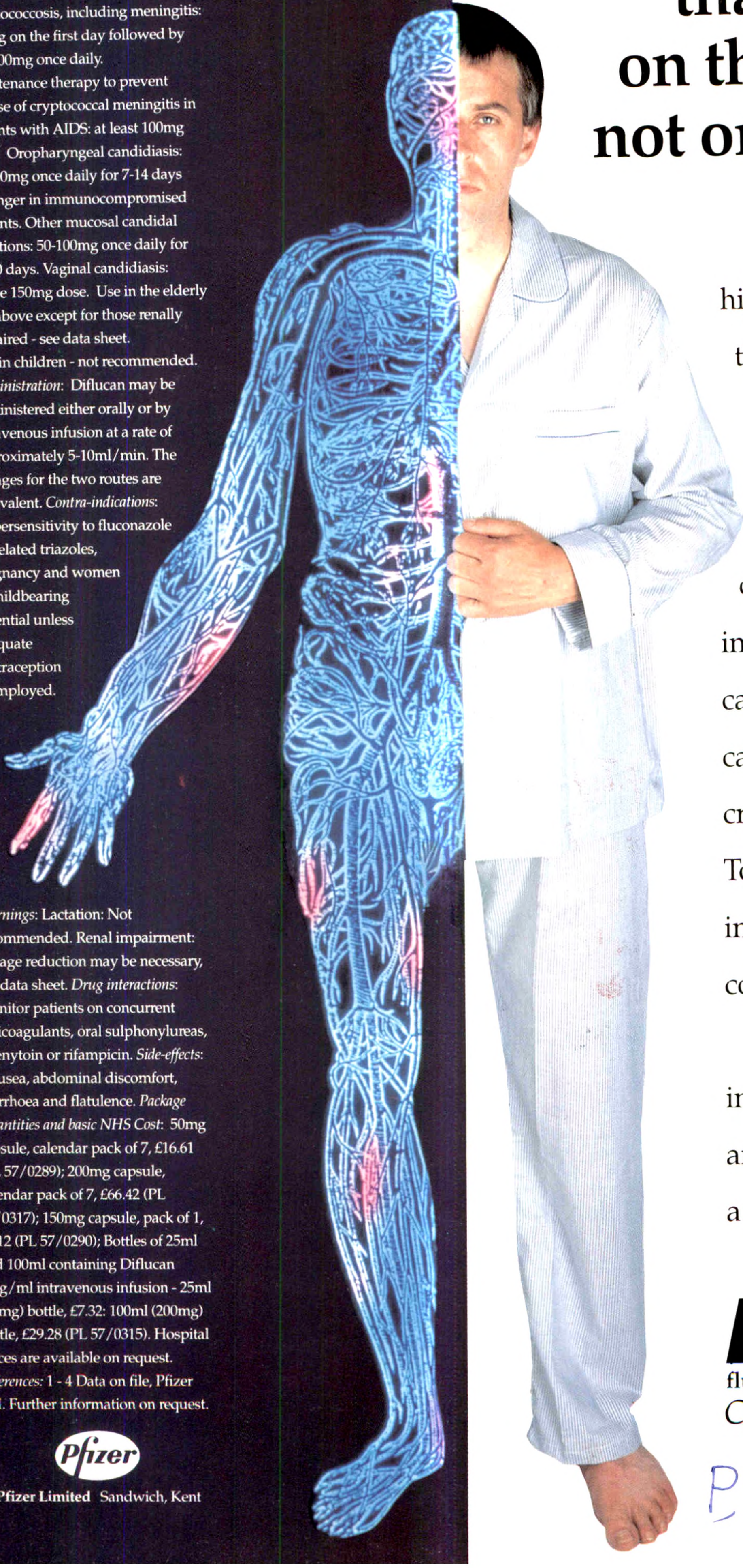

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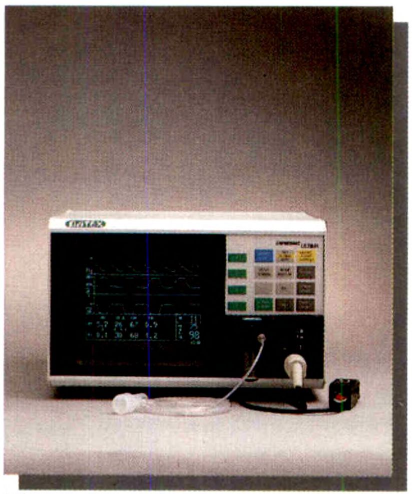

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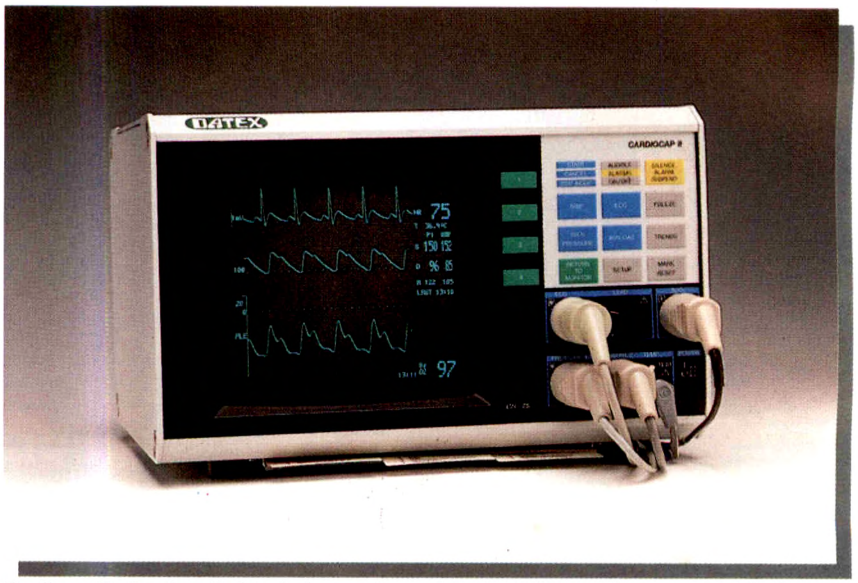

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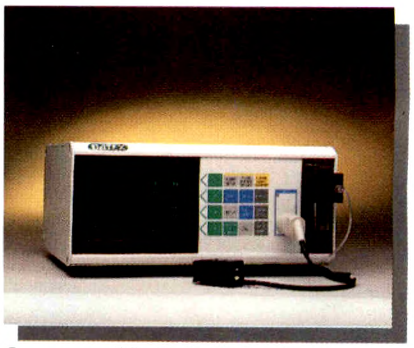

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Anaesthesia, 1992, Volume 47, pages 1–2

Editorial

A golden jubilee to celebrate

'A purified extract of curare (Intocostrin) has been administered intravenously to 25 patients under light general anesthesia. In each case temporary but complete muscular relaxation was rapidly produced with apparently no harmful effect'.

Fifty years ago, Griffith and Johnson [1] thus summarised the results of their historic clinical trial of Intocostrin (Squibb), the first relaxant to be used with posological reliability. Their first patient was treated on Friday, 23 January 1942, in the Homeopathic Hospital, Montreal. Their report was free of drama and sensationalism. If there were any excitement in the operating theatre on that day, it is, perhaps, suggested in the description of an abdomen, 'as soft as dough'. Nevertheless, a revolution in the treatment of the patient undergoing surgery had started, hardly less radical than that which followed the clinical trials of ether by Clark of Rochester, New York and Crawford Long of Jefferson County, Georgia which took place almost exactly a century earlier.

It is fitting in this jubilee year to review the events which led up to that climactic experiment in Montreal and to examine its effects.

That first paper was typical of Harold Griffith, a quiet and rather shy man. He sought neither fame nor greatness, but he was indeed to achieve both and to receive international acclaim and distinction. With characteristic humility and commendable honesty he has related how, 2 years previously, when Dr Louis H. Wright of New York, suggested to him that curare might be useful in anaesthesia, he 'laughed at the idea' [2]. Then he thought about it for more than a year and, after further persuasion by Wright, he succumbed.

The story leading to such a denouement on that Friday in Montreal was an example of how many discoveries in medicine are the result of prodromal events which have demanded imagination and courage. In 1938–39, on the suggestion of McIntyre [3], Professor of Physiology and Pharmacology at the Nebraska School of Medicine, Dr Bennett had demonstrated the removal of the traumatic effects of convulsive therapy by a prophylactic dose of a curare preparation which had been extracted from a known plant source in McIntyre's laboratory. It was standardised by acetylcholine antagonism, using the frog gastrocnemius preparation. Bennett later used Intocostrin and his results were reported in January 1940 [4]. It must have been around that time that Wright made his suggestion to Griffith.

Another remarkable man, in a story featuring several such, was Richard Gill [5]. He played a key role. In 1932, Gill developed multiple sclerosis. Whilst in a severe relapse and suffering painful muscle spasms, he developed an obsessional interest in the therapeutic potential of the South American arrow poison. He had studied the Indians' method of preparing it and the materials used whilst he was working for a rubber company on a station in the Ecuadorian rain forest. His obsession resulted, in 1938, in an expedition to Ecuador of 6 months' duration. He returned with a huge consignment of the plants which became the source from which McIntyre prepared his extract and Squibb their Intocostrin.

In recalling these events, however, it should not be forgotten that there had been attempts before Griffith to use curare during anaesthesia: by Läwen [6] in Leipzig, in 1912, and in London, in 1928, when de Caux, at the North Middlesex Hospital, used an aqueous extract of curare to supplement nitrous oxide, oxygen anaesthesia [7]. Like other physicians of the time, who attempted to use the arrow poison in the treatment of various convulsive and spastic conditions, they were frustrated by the unpredictable effect of their preparations.

However, we in Britain cannot claim to have been quickly off the mark. During the war communications were difficult and American anaesthetic journals were not easily obtained and, when this new development was rumoured or confirmed, it was far from easy to obtain Intocostrin. It is certainly tantalising to recall that Harold King, a chemist working in London in the Medical Research Institute, published a paper in 1935, announcing his successful extraction from tube curare of its active principle, the crystalline alkaloid d-tubo curarine [8]. It was in fact July 1945 before the first papers on the use of curare in anaesthesia appeared in the British medical press. Mallinson [9] described a series of 40 patients to whom he had given Intocostrin during anaesthesia. In the same issue of the *Lancet*, Griffith [2] reviewed his experiences with Intocostrin and 'a new preparation, d-tubocurarine' and ended his review with the modest opinion that 'it will probably have a permanent place in anaesthesia'. Since the summer of 1944, as the result of a fraternal relationship with Medical Officers of an American Bomber Squadron, stationed at Burtonwood, work had been proceeding on Merseyside, using at first Intocostrin and very soon, as supplies of the American preparation dried up, tubocurarine [10]. In January 1946, a series of abdominal and thoracic operations in which tubocurarine was used was described to a meeting of the Liverpool Medical Institution and a larger series of over 1000 cases presented to the Section of Anaesthetics of the Royal Society of Medicine 3 months later [11].

In the early days, curare was considered just as another useful tool in the anaesthetist's bag which would help to avoid the embarrassing protrusion of the abdominal contents on closure of the abdomen. Some of the writer's generation will remember the use of a tablespoon by the surgeon on occasions when the patient was 'too light'! Now, not only was the tablespoon banished but so also was that bane of the anaesthetist, laryngeal spasm. From the patient's viewpoint, the benefits were manifest. Severe attacks of pneumonia, sometimes fatal, which not infrequently used to follow upper abdominal operations, became rare, provided that full recovery of respiratory function was achieved, if necessary by the use of the antidote neostigmine. Failure to assure this, before returning patients to the ward, accounted for the dire results reported in 1953 from 10 University Hospitals in the United States [12]. But the most beneficial effect of curare was to make

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deep anaesthesia a thing of the past. As early as 1944, Knight noted that the use of curare 'helps us to realise that deep general anaesthesia is more damaging and more shock producing than even the trauma of surgery' [13]. Rapid recovery became the norm as did absence of the toxic effects of anaesthetic drugs. Circulatory disturbances were minimised. Indeed, in the 1940s and 1950s, a change occurred in the practise of anaesthesia of a magnitude which must be difficult for the practitioner of today fully to imagine.

An enormous amount of research has been carried out during these 50 years and many synthetic relaxant drugs produced as subsitututes for tubocurarine. It is, perhaps, fair to suggest that two may be regarded as markers for future development: suxamethonium, introduced in 1951, because of its short action, and the more recently produced atracurium, the first relaxant to have a mode of degradation independent of hepatic and renal functions.

So, there can be no question that patients benefited directly from the event of January 1942, but there were other very important effects which were of indirect benefit to them. Instead of being limited to thoracic units IPPV became a feature of daily practice with far-reaching results in the treatment of paralytic conditions such as poliomyelitis, severe neuropathies and myasthenic conditions. With better understanding of blood gas and electrolyte disturbances the way was paved towards intensive therapy. The respiratory management of the paralysed patient demanded the pursuit of knowledge of respiratory physiology and of pharmacology of a standard which was daunting to many anaesthetists of the time. Anaesthesia had developed from a clinical art into a clinical science. When, in 1946, the National Health Service was being planned, there was serious debate, in the corridors of power, as to whether practitioners in some specialties would merit consultant status and the grade of Senior Hospital Medical Officer was created. Anaesthesia was one such specialty. In the opinion of the writer, it is reasonable to suggest that a main factor which led to a decision in favour of the consultant grade for anaesthetists was this change from empiricism to science, a change which extended the horizons of both anaesthetists and surgeons. Education in the basic sciences thus became imperative. A two-part Diploma in Anaesthetics replaced the one-part examination and there arose the compelling need for a qualification of the same standard as that of a Fellowship in a Royal College. There was strong support from senior surgical colleagues and from anaesthetists [14]. The threat to the future of the specialty was finally removed when, in 1948, a Faculty of Anaesthetists was formed within the Royal College of Surgeons.

There is to be a commemorative meeting in Montreal from 21–24 May 1992. In the half-century, there has been significant clinical and scientific work performed in the field of relaxants on this side of the Atlantic and it is to be hoped that a strong representation from the United Kingdom will be able to attend and make a worthy contribution.

Griffith was affectionately known as 'Uncle Harold'. It is thanks to his daring that there is indeed much for anaesthetists, surgeons and patients to celebrate in this 50th year.

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Anaesthesia, 1992, Volume 47, pages 3–6

Colloid solutions in the critically ill

A randomised comparison of albumin and polygeline. 1. Outcome and duration of stay in the intensive care unit

M. A. STOCKWELL, N. SONI AND B. RILEY

Summary

All patients admitted to an Intensive Care Unit were randomised to receive all volume replacement fluid as either human albumin solution or a synthetic colloid. A total of 475 patients were admitted during the study period. Patients' age, sex, APACHE score and calculated risk of death were assessed on admission. Outcome was assessed as length of Intensive Care stay and mortality. There was no difference between the groups. Subgroups of patients with APACHE score greater than 10, calculated risk of death greater than 50% and length of stay greater than 5 days were also evaluated but no significant differences were found between treatment groups. The use of albumin rather than 3.5% polygeline for volume replacement in the Intensive Care Unit has no influence on outcome.

Key words

Fluid balance; intravenous fluid, colloid.
Protein; albumin.

The use of colloid solutions for volume replacement in the critically ill patient has become more widespread, as the crystalloid–colloid debate has swung in favour of colloids [1, 2]. The type of colloid used is contentious but human albumin solution is generally considered to be the fluid of choice despite the absence of supportive data in the literature. This is based on a theoretical appraisal of the potential benefits of using an agent which has multiple physiological roles as well as the observation that hypoalbuminaemia has pathophysiological associations. The former include the ability to bind reversibly anions, cations and many drugs [3], its role as a transport mechanism, the effective support of colloid osmotic pressure, enhancement of aspects of clotting and scavenging of free radicals [4]. The main pathophysiological feature is the association between malnutrition, of which hypoalbuminaemia is often a feature, and morbidity; this association is well documented, although far from conclusively proven [5, 6].

The available alternative fluids are a range of synthetic colloids which lack some of the physiological benefits and have several potential disadvantages, such as interference with clotting and a variable effect on colloid osmotic pressure, as well as postulated (but unproven) effects on the efficiency of the reticuloendothelial system [7].

In recent years the supply of human albumin in parts of the UK has been restricted by the logistics of collection, processing and distribution, and the use of synthetic agents has increased dramatically.

The aim of this study was to investigate whether the use of a synthetic colloid solution instead of a human albumin solution for intravenous volume replacement in the critically ill has a detectable effect on outcome.

Patients and methods

All patients over the age of 18 years admitted to the Intensive Care Unit (ICU) were randomised to receive either 4.5% human albumin solution (group A) or a synthetic colloid, polygeline (Haemaccel, Hoechst UK) (group B), for intravenous volume replacement. There were exclusions from the study; these were patients under the age of 18 years and those admitted for cardiac monitoring or cardiac thrombolytic therapy. On the basis of a possible difference between the two groups, in the order of 10% with regard to mortality (estimated as approximately 20%), a population size of 250 in each group was required (5% type 1 and 10% type 2 error).

Colloid solutions were administered for intravascular filling as determined either by normal clinical parameters of perfusion, blood pressure and urine output or by more invasive measurements (central venous or pulmonary artery pressures and derived indices) where indicated.

All patients admitted to the study received basal fluid requirements with crystalloid solutions. All patients received parenteral nutrition, which was started within 48 h of admission if the enteral route was inappropriate. Blood

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Table 1. Demographic and outcome data for all patients. Values are median (range) or number.

Variable	Group A $n = 226$	Group B $n = 249$	p value
Age	60 (18–86)	64 (18–88)	0.0075
APACHE II score	12 (0–43)	14 (1–53)	0.06
Risk of death	0.10 (0.01–0.96)	0.11 (0–0.98)	0.221
Sex M:F	159:67	162:87	0.219
Died	45	50	
Expected to die	14	17	
Survived	167	182	0.959
ICU stay; days	3 (0–87)	3 (0–87)	0.8

(as packed cells) and clotting factors were given to maintain a minimum haematocrit of 30% and normal coagulation indices. Serum albumin concentration was not used as an indication for albumin therapy, but if clinical problems such as peripheral or pulmonary oedema were considered to be a direct consequence of hypoalbuminaemia, human albumin solution 20% was given.

The diagnosis, age and sex of each patient was recorded on admission. The Acute Physiology and Chronic Health Evaluation (APACHE II) score was determined from the worst results in the first 24 h, as described by Knaus [8], and a risk of death index calculated. Daily records were kept of all colloid solutions and blood products infused. Serum albumin and total protein concentrations were measured daily. Outcome was recorded in three categories: 1, survived to leave Intensive Care; 2, discharged but not expected to survive; 3, died in the ICU. The length of stay in the ICU was recorded for each patient as an index of morbidity, as it was felt that a patient may have a longer course which would not necessarily influence definitive outcome.

Data from all patients were analysed with respect to the treatment provided (synthetic colloid versus albumin). Three subgroups were chosen as representative of patient populations which were likely to be influenced by these treatments. These groups were patients with high APACHE scores (> 10), a calculated risk of death index > 50% [8] and a length of stay > 5 days.

Statistical analysis was by the Mann–Whitney *U* and Chi-squared tests. Logistic regression analysis of 10 variables was also performed (age, sex, study group, APACHE score, calculated risk of death, volume of blood products given, volume of synthetic colloid, volume of albumin and length of stay against outcome) to identify any measured variable with an independent effect on outcome.

This study was approved by the Ethics Committee of Westminster Hospital.

Results

The data for all 475 patients are summarised in Table 1. The categories of admission can be characterised as 11% trauma, 30% postoperative, 29% general medical, 13% respiratory failure and 17% cardiac. The groups were similar in respect of APACHE score, risk of death distribution and gender. There was no significant difference in the volume of blood products, other than albumin, given to the two groups: group A, mean 1.45 l (range l 0–29); group B mean 1.39 l (range 0–66) (p = 0.65, Mann–Whitney *U* test). There was a statistically significant difference in age.

There was no significant difference in either length of stay (group A median 3 days, range 0–87; group B median 3.6 days, range 0–87; p = 0.8), or outcome (survival group A 73%; group B 73%; p = 0.95). Analysis of the subgroups showed no significant differences in sex distribution, APACHE scores, calculated risk of death, length of stay or outcome (Tables 2–4).

The volumes of all fluids received by the two treatment groups and within the subgroups were similar and there was no difference in the volume of crystalloid administered. When all patients were considered, the mean volume of colloid solution in group A was 2.51 l (range 0–30) and in group B 3.06 l (range 0–30) (Mann–Whitney *U* test p = 0.035). The difference was not significant in any of the three subgroups.

Seventeen patients were given concentrated albumin,

Table 2. Demographic and outcome data for all patients with an APACHE II score > 10. Values are median (range) or number.

Variable	Group A $n = 131$	Group B $n = 157$	p value
Age	61 (18–82)	67 (19–88)	0.007
APACHE II score	16 (11–43)	18 (11–53)	0.079
Risk of death	0.22 (0.01–0.96)	0.25 (0.01–0.98)	0.245
Sex M:F	100:31	102:55	0.036
Died	42	47	
Expected to die	12	16	
Survived	77	94	0.906
ICU stay; days	4 (0–87)	3 (0–87)	0.8

Table 3. Demographic and outcome data for all patients with a risk of death index of greater than 0.5. Values are median (range) or number.

Variable	Group A *n* = 23	Group B *n* = 39	p value
Age	59 (18–80)	70 (27–84)	0.044
APACHE II score	27 (22–43)	28 (18–53)	0.30
Risk of death	0.66 (0.51–0.96)	0.66 (0.51–0.98)	0.30
Sex M:F	17:6	22:17	0.17
Died	16	22	
Expected to die	2	2	
Survived	5	15	0.174
ICU stay; days	2.0 (0–41)	3.0 (0–87)	0.229

four in group A and 13 in group B. The median volume in group A was 250 ml (range 250–400) and in group B 250 ml (range 100–2000).

The data were submitted to a logistic regression procedure. The APACHE score and the volume of blood products infused were significant in relation to outcome. (APACHE score, $p < 0.00001$; blood products $p = 0.0005$). No other variable achieved statistical significance at the chosen level. Specifically, the treatment group to which the patient was assigned had no influence on outcome ($p = 0.7338$).

A further logistic regression procedure was performed allowing for the effect of age, sex, blood products (excluding albumin) received and APACHE II score. The result was an odds ratio of 0.95 with 95% confidence limits of 0.74–1.22 suggesting that the use of albumin rather than synthetic colloid for volume replacement had no influence on outcome.

Discussion

This study demonstrates no difference in outcome or length of stay in the ICU when polygeline is used as a substitute for human albumin solution for volume replacement. When subgroups which might be considered at greater risk than the majority of patients (namely those with a high APACHE score, those with a high predicted risk of death, and those who require a long duration of stay in the ICU) were analysed, no difference emerged. Although the patients who received polygeline required slightly more fluid overall, this was not sustained in all three subgroups and did not achieve statistical significance.

The age difference between the groups was small, but achieved statistical significance. The authors are unable to explain this difference as patients were allocated randomly to either group. The logistic regression did not demonstrate a significant influence of age on outcome nor, when age was allowed for, did the choice of colloid solution affect outcome.

Seventeen patients received concentrated albumin. These were almost all long-stay patients and the larger volumes were given in association with dialysis. It was considered essential to allow this modification of the protocol as so many clinicians regard hypoalbuminaemia to be the cause of peripheral and pulmonary oedema. Concentrated albumin was not used in patients with pulmonary oedema and its clinical impact on peripheral oedema was considered minimal and the effects on serum albumin transient. As the study progressed, the indications for its use diminished and it is the authors' contention that its limited use did not significantly alter any clinical course.

The results of this study are somewhat surprising. There are many theoretical advantages in the use of albumin for volume replacement. Albumin has a unique physiological role which is unmatched by synthetic substitutes. The reversible binding of both anions and cations allows albumin to act as a transport system for many substances, including metabolic substrates and drugs. This feature enables it to bind exogenous toxins, which may have theoretical advantages in the critically ill [4]. It has also been postulated that albumin can function as a free radical scavenger [9]. Furthermore, albumin has a fundamental role in the maintenance of colloid osmotic pressure.

Synthetic colloids lack many of these characteristics and also have potential adverse allergenic, rheological and coagulation effects [6, 7, 10]. Despite these problems, these agents are used widely for volume replacement, partly because they do support colloid osmotic pressure. In this

Table 4. Demographic and outcome data for all patients with a length of stay greater than 5 days. Values are median (range) or number.

Variable	Group A *n* = 65	Group B *n* = 75	p value
Age	60 (19–81)	63 (20–82)	0.15
APACHE II score	14 (4–35)	15 (2–37)	0.70
Risk of death	0.15 (0.02–0.60)	0.15 (0.01–0.85)	0.825
Sex M:F	50:15	55:20	0.219
Died	17	21	
Expected to die	8	7	
Survived	40	47	0.84
ICU stay; days	11 (6–87)	10 (6–87)	0.925

regard, they are not dissimilar from albumin, although the specific pressures generated are related to the molecular sizes of the different solutions [11].

The second aspect of the use of albumin is the support of the serum albumin concentration itself. There is a considerable body of evidence demonstrating an association between hypoalbuminaemia and morbidity [12, 13]. Kaminski and Williams [14] have reported that the use of albumin to supplement parenteral nutrition can result in a sustained improvement in serum albumin concentration but commented that albumin alone will not achieve this and that the benefits of this correction on morbidity are unclear. Foley *et al.* [15] have suggested that as iatrogenic elevation of serum albumin fails to reverse the high morbidity, the relationship may not be causal. It is clear that it is usually the underlying pathology which is the cause of hypoalbuminaemia and it is the correction of that pathology which results in a recovery of serum albumin concentration [15–17]. There is little convincing evidence to suggest that the routine use of exogenous albumin alone to support serum albumin concentration is of benefit, and no evidence to show that the use of albumin as volume replacement is likely to be advantageous in this regard.

The third aspect of the use of albumin is the financial consideration. The major advantage of synthetic substitutes is in their relative economy. At the time of this study, albumin was 20 times the cost of polygeline. The volume of synthetic agent used was 1.25 times the volume of albumin, reducing the potential saving to a 14-fold difference. In 226 patients, 533 l of human albumin solution were used and in 249 patients, 754 l of synthetic colloid. The cost of albumin was £53 245 as against £3769 for synthetic solutions.

The issue of which colloid to use is contentious and further work is obviously needed in this important but generally neglected area. The conclusion from this study did not support the hypothesis that 4.5% albumin solution is a better volume replacement therapy than a synthetic agent in the critically ill. The widely accepted but largely theoretical benefits of albumin did not appear to influence outcome and our results justify the routine use of synthetic colloids for volume replacement in the critically ill.

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Colloid solutions in the critically ill

A randomised comparison of albumin and polygeline 2. Serum albumin concentration and incidences of pulmonary oedema and acute renal failure

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Summary

All patients admitted to an Intensive Care Unit were assigned randomly to one of two groups, A and B. Group A received colloid volume replacement as 4.5% albumin whilst group B received a synthetic colloid, polygeline. This study describes the changes in serum albumin concentration in survivors and nonsurvivors in the two groups during their stay in the Intensive Care Unit. The incidences of renal failure and pulmonary oedema were also assessed. Serum albumin concentration decreased in all nonsurvivors. In survivors the serum albumin concentration decreased to a greater extent in the synthetic colloid group than in the albumin group. Despite the differences in serum albumin concentration there were no significant differences between the groups in the incidences of pulmonary oedema or renal failure.

Key words

Fluid balance; intravenous fluid, colloid.
Protein; albumin.

Albumin solution is used commonly for volume replacement in the critically ill. The choice of resuscitation fluid has been discussed extensively in the literature, with emphasis almost entirely on the acute haemodynamic effects of available solutions [1]. Many of the arguments supporting the use of albumin relate to the potential physiological advantages of this solution in the medium to long term but there are little or no data confirming the validity of these considerations. The theoretical arguments which would suggest that albumin has advantages over synthetic equivalents [2] include its ability to bind anions and cations [3], its role as a scavenger of free radicals [4] and its influence on microvascular integrity.

A study was undertaken to determine whether these differences resulted in a measurable change in outcome and the results are described elsewhere [5]. Daily serum albumin measurements were made but no action was taken to correct the serum albumin concentration towards normal. This paper describes the changes in serum albumin concentration which occurred when synthetic colloid was used rather than albumin as a volume replacement fluid in critically ill patients. In addition, two specific problems have been described in relation to the use of colloids and the maintenance of serum albumin. The first is renal failure and the second the development of pulmonary oedema. The occurrences of these complications were assessed.

Patients and methods

Patients over the age of 18 years admitted to the Intensive Care Unit (ICU) were assigned randomly to receive either 4.5% human albumin solution (group A) or polygeline (Haemaccel, Hoechst UK) (group B) for intravenous volume replacement.

Entry criteria and treatment are described in detail in the accompanying paper [5]. Blood was sampled daily for determination of serum albumin concentration using the Bromcresol Purple Method (BPM), calibrated with SPS-01 human albumin based standard (UK Supraregional Assay Service, Protein Reference Units). This was measured on a Hitachi 717 Automatic Analyser (Boehringer Mannheim Ltd, Lewes, Sussex). This method has been evaluated and there is no significant difference between this and an immunoprecipitation method down to a plasma albumin concentration of 6 $g.l^{-1}$. Age, sex, diagnosis, calculated risk of death, length of stay in the intensive care unit and outcome were also recorded.

A subgroup of patients was selected from the first 380 patients admitted to the trial. This subgroup consisted of those patients who remained in the ICU for 5 days or more. They were assessed for the appearance of pulmonary oedema and for acute renal failure. Pulmonary oedema was defined by the radiological appearance diagnosed by a

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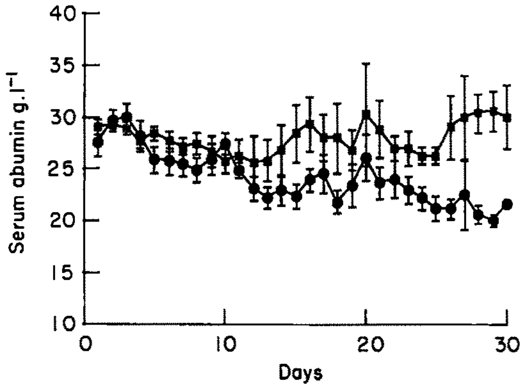

Fig. 1. Mean serum albumin concentrations in patients treated with albumin (group A). Bars indicate SEM. ■, Survivors; ●, nonsurvivors.

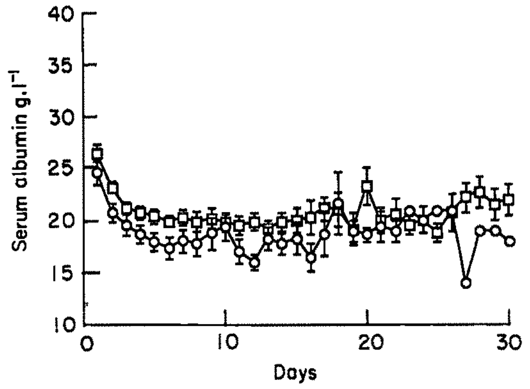

Fig. 2. Mean serum albumin concentrations in patients treated with synthetic colloid (polygeline). Bars indicate SEM. □, survivors; ○, non survivors.

radiologist who was unaware of the study. Renal failure was defined as a serum urea concentration of greater than 30 mmol.l^{-1}, or the requirement for renal support by dialysis. Patients staying longer than 5 days were chosen as it was felt that in this population the secondary development of renal failure or pulmonary oedema was more likely to reflect intensive care management or treatment differences than pre-existing pathology.

Statistical analysis

Mean albumin values were calculated for each day in each group and the standard error of the mean used as an index of spread. Chi-squared tests with Yates' correction were used to determine the significance of treatment on the incidence of pulmonary oedema and renal failure.

This study was approved by the Ethics Committee of Westminster Hospital.

Results

A total of 475 patients entered the study. Of these, 226 received human albumin solution (group A) and 249 polygeline (group B). Among the patients who received albumin, the survivors maintained a low but reasonably constant serum albumin concentration while the nonsurvivors showed a tendency for the serum albumin concentration to decrease (Fig. 1.) The difference achieved statistical significance at day 24, although the number of patients who remained in ICU for longer than 24 days was small. This difference in trend was not observed in the patients who received synthetic colloid; the survivors and nonsurvivors demonstrated a low serum albumin concentration from an early stage (Fig. 2). When the nonsurvivors in the two groups are compared, the serum albumin concentration decreased more rapidly in the first few days in the synthetic colloid group (Fig. 3). Among the survivors, patients who received synthetic colloid had a considerably lower serum albumin concentration from a very early stage than those who received albumin (Fig. 4).

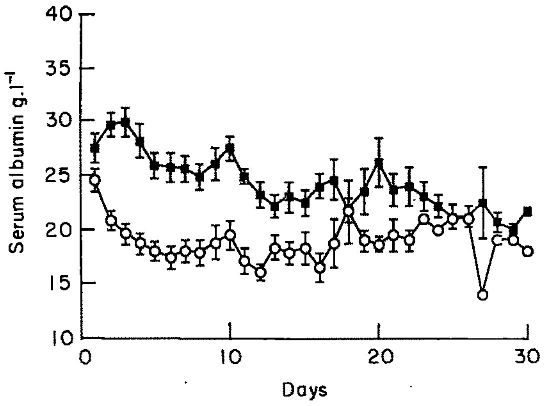

Fig. 3. Mean serum albumin concentrations in nonsurvivors treated with albumin (■) or synthetic colloid (○). Bars indicate SEM.

Of the 380 patients studied for evidence of either pulmonary oedema or acute renal failure, 53 patients in group A and 59 patients in group B stayed in the ICU for five days or more. In group A three patients developed both acute renal failure and pulmonary oedema, two developed acute renal failure without pulmonary oedema and six developed pulmonary oedema. In group B, five developed renal failure and pulmonary oedema, six had renal failure without pulmonary oedema and nine had pulmonary oedema. There were no significant differences between groups in the incidences of renal failure or pulmonary oedema.

Discussion

The changes in serum albumin concentration are of some interest. Admission levels reflect surgery or previous treat-

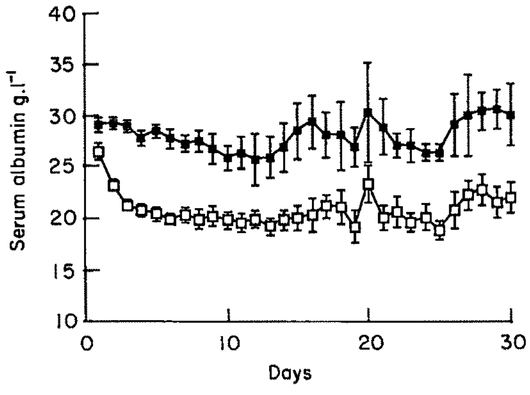

Fig. 4. Mean serum albumin concentrations in survivors treated with albumin (■) or synthetic colloid (□). Bars indicate SEM.

ment prior to admission, and may be low. It is also important to note that in this study patients were monitored up to discharge from ICU not to the point of discharge from hospital and it is well documented that recovery of serum concentrations may take a long time, despite total parenteral nutrition (TPN) [6]. Indeed this has been part of the argument for active supplementation of TPN with albumin [7, 8].

The results of this study support the concept that serum albumin concentration in patients who survive is maintained better when albumin is used for volume replacement. The most interesting observation is the low concentration of serum albumin in survivors who received predominantly gelatin; the serum albumin concentration decreased dramatically following admission and remained low. However, there were no differences in outcome or length of stay between the two treatment groups [5]. The implication is that albumin administration tends to support the serum albumin concentration better than synthetic colloid but that this does not confer benefit in terms of outcome.

This contention has been supported by evidence derived from studies involving different approaches to the use of albumin. Foley *et al.* [9] used concentrated albumin to supplement and correct hypoalbuminaemia but failed to show that this influenced either morbidity or mortality. They commented that the serum albumin concentration could be increased but that this did not have a causal relationship with outcome. The unadulterated serum albumin concentration reflects the underlying pathology and the changes in concentration may indicate response to treatment. These observations and the results reported here might suggest that albumin administration, without contributing to measurable therapeutic benefit, may actually confound the interpretation of serum albumin concentrations.

A different aspect of the use of albumin has been the support of colloid osmotic pressure and several studies have addressed this issue. Grootendorst and von Wilgenburg [10] used albumin to sustain colloid osmotic pressure but concluded that it is questionable whether albumin is the agent of choice to support colloid osmotic pressure; this supported the conclusions of Grundmann and von Lehndorff [11].

The findings in our study are passive and no specific attempt was made to correct either the serum albumin concentration or the colloid osmotic pressure. Nevertheless the findings do bear relevance to the studies which have addressed these points specifically. Despite much theoretical speculation, there is little evidence to suggest that albumin is the optimal agent for maintenance of colloid osmotic pressure [2, 12] and this argument for its use in volume replacement therapy is probably fallacious.

The incidence of pulmonary oedema in ICU was low. Only patients who remained in ICU for longer than five days were studied in an attempt to exclude those who presented with pulmonary oedema as part of their primary illness. Late-onset pulmonary oedema is more likely to reflect aspects of management which would include the influence of fluid replacement therapy. The serum albumin concentrations were low in many of these patients, as can be seen in Figures 1–4. It has been assumed that a low serum albumin concentration in the critically ill is a significant cause of pulmonary oedema but there is little evidence in the literature to support this association. Oedema is common in the critically ill but is related usually to a specific cause. All the serum albumin concentrations were low in group B patients, but despite this there was a relatively small incidence of oedema. This suggests that the role of serum albumin in the development of pulmonary oedema may have been overstated.

The other area evaluated was the incidence of renal failure in the two treatment groups. Both agents are used for the correction of hypovolaemia and any difference in the incidence of renal failure which may be related to one or other agent would be of concern [13]. However, there was no significant difference between the two groups.

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The 'cuff-leak' test for extubation

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Summary

The 'cuff-leak' test, which involves demonstrating a leak around a tracheal tube with the cuff deflated, has been advocated to determine the safety of extubation in patients with upper airway obstruction. In 62 such patients we were able safely to extubate all patients with a cuff leak. Two patients extubated without cuff leak required reintubation and in five patients who repeatedly failed the test, tracheostomy was performed. Subsequently, we extubated 10 patients who were stable on spontaneous ventilation and did not have cuff leak; three later required tracheostomy and seven were uneventfully extubated. While the presence of cuff leak demonstrates that extubation is likely to be successful, a failed cuff-leak test does not preclude uneventful extubation and if used as a criterion for extubation may lead to unnecessarily prolonged intubation or to unnecessary tracheostomy.

Key words

Airway; obstruction.
Equipment; tubes, tracheal.
Equipment; cuffs, tracheal.

Patients with upper airway obstruction or oedema due to trauma or surgery constitute major airway management problems. Extubation of such patients may be life-threatening if significant airway obstruction is present, particularly when the jaws have been immobilised. A study of failure of extubation in 700 consecutive surgical patients identified no valid predictors of extubation failure [1]. The presence of a leak around the tracheal tube has been shown to be a useful, if not universal, indicator of successful extubation [2] and postextubation stridor in children [3], and has been described as a predictor of successful extubation in 10 patients with upper airway obstruction [4]. We have evaluated this technique in two studies involving 72 patients in an intensive care unit.

Method

In the initial study, 62 patients with upper airway problems were evaluated prospectively using the cuff-leak test. When the patients were fully awake and able to breathe spontaneously via the tracheal tube, the tracheal tube cuff was deflated, the tube occluded, and the presence or absence of a peritubular leak during spontaneous ventilation was assessed. If a leak was detected, the patient was extubated. If no leak was detected the cuff was left deflated and the patient was re-evaluated later. Evaluations were not performed at particular times, but the initial one was performed on morning rounds and subsequent evaluations on routine rounds. No patients were extubated after 1800 h, since the staffing in this unit is such that the immediate presence of a doctor experienced in difficult intubation cannot be guaranteed outside regular hours.

The second group consisted of 10 consecutive patients who had no cuff leak on occlusion of the tracheal tube with the cuff deflated. These patients were extubated in the presence of two doctors who were prepared to induce anaesthesia and reintubate if necessary. One patient was extubated over a bronchoscope and nine patients over a bougie left in the trachea to facilitate reintubation. Patients who required reintubation were transferred to the operating room for direct laryngoscopy with a rigid laryngoscope and straight and angled telescopes and the laryngopharynx, vocal cords and subglottic region were examined. Tracheostomy was performed if significant laryngeal pathology was demonstrated.

Results

Data for the first 62 patients are summarised in Table 1. Most patients were extubated successfully after one or two evaluations. Two patients were extubated after six and four attempts respectively and both required reintubation, one within 2 h of extubation and one after 14 h.

Five patients had tracheostomies after repeated failures

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Table 1. Characteristics of 62 patients with upper airway problems assessed by cuff leak test.

Reason for admission	Number	Mean number of leak tests performed	Time to extubation after admission to unit mean (SD) in h	Patients passing leak test and requiring reintubation	Patients failing leak test requiring reintubation	Patients repeatedly failing test and undergoing tracheostomy
External fixation facial or mandibular fractures	28	1.8	23 (15 h)	0	1	1
Angioneurotic oedema	3	1	10 (3)	0	0	0
Radical head and neck dissection	12	1.9	17 (4)	0	0	1
Cervical fusion for trauma	1	6	72	0	1	0
Elective major facial reconstruction	7	2.1	16 (4)	0	0	0
Head and neck tumours	2	3	19 (7)	0	0	1
Paraglottic swelling secondary to subclavian artery haemorrhage	1	3	18	0	0	0
Thyroid surgery for obstruction, retrosternal goitre	6	1.2	56 (16)	0	0	2
Skin grafts to neck	1	2	15	0	0	0
Facial trauma, no surgery	1	2	12	0	0	0

to extubate. Two patients were extubated in the absence of a demonstrable cuff leak and required reintubation. One was extubated in the absence of a demonstrable air leak because it was felt that the tracheal tube was too large and was thus contibuting to the airway obstruction. The second was extubated on the instructions of the primary care consultant.

The characteristics of patients in group 2 are shown in Table 2. Seven of 10 patients with no leak were extubated uneventfully and three required reintubation. Laryngoscopy in these patients showed significant pathology and they subsequently underwent tracheostomy.

Discussion

The results from the initial group of patients studied suggest that when a cuff leak is present in patients with

Table 2. Consequences of extubation of 10 consecutive patients with upper airway problems and failed 'cuff leak' test.

Patient	Diagnosis	Time after admission	Consequences	Laryngoscope findings in reintubated patients
1.	Post-thyroidectomy secondary haemorrhage	1 day	Obstructed Reintubated Tracheostomy	Oedema of epiglottis, arytenoids, false cords, trachea
2.	Postoperative; commando operation	12 h	Uneventful	
3.	Postoperative hemiglossectomy; chronic airways disease	36 h	Uneventful	
4.	Wired mandibular and facial fractures; lacerated tongue	12 h	Obstructed Reintubated Tracheostomy	Swelling of pharynx and tongue. Oedema of epiglottis, and arytenoids
5.	Staphyloccal pharyngolaryngitis	36 h	Uneventful	
6.	Bilateral mandibular osteotomies	12 h	Uneventful	
7.	Coronary artery bypass graft, asthma; postextubation stridor	48 h	Obstructed Reintubated Tracheostomy	Subglottic oedema and granulation tissue, posterior ulceration of left vocal process and arytenoid
8.	Multiple trauma; facial trauma, fractured mandible, fractured C5 vertebra	7 days	Uneventful	
9.	Anterior and posterior cervical fusion; swollen neck	8 h	Uneventful	
10.	Emergency oesophagectomy with anastomosis in neck; chronic airways disease	36 h	Uneventful	

upper airway problems, successful extubation is possible. No patient with a leak required reintubation.

Our concern, when we examined the results in this group, was that extubation may be delayed, or unnecessary tracheostomy performed, when a cuff leak could not be detected and this led us to study the second group in whom the tracheal tube was removed when no cuff leak was present. This confirmed our suspicions, that absence of cuff leak did not mean that the tracheal tube could not be removed with safety. It is our usual practice to base the decision on whether or not to perform tracheostomy on expert direct laryngoscopy with the tracheal tube removed under controlled conditions. If the presence of laryngeal injury suggests that the translaryngeal tracheal tube is contraindicated, then tracheostomy is performed. This was the case in all three group 2 patients who required reintubation.

These data suggest that a cuff leak around the tracheal tube when the cuff is deflated is a very sensitive predictor of successful extubation in patients with possible airway obstruction. However, it is clear that the test is not specific, since a significant proportion of patients who have no leak can also be successfully extubated. Further, a number of patients who fail the cuff-leak test will have significant laryngeal or related pathology and may fail extubation, and in these patients tracheostomy may be required. Extubation in patients with no leak around the tracheal tube should be undertaken only in the presence of experienced personnel who are able to effect an often difficult reintubation. If reintubation is required, formal endoscopic inspection of the larynx should be performed. Similar results have been found with children: reintubation was necessary in five of 30 patients with no cuff leak although tracheostomy was only performed in one [3].

Acknowledgment

We acknowledge the expertise of Dr B. Benjamin who performed the laryngoscopies, and tracheostomies in the second group of patients.

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Response to the Valsalva manoeuvre after spinal anaesthesia

A. G. MACFIE AND J. BRIMACOMBE

Summary

The waveform from a Criticare 504 pulse oximeter was recorded during the performance of a standard Valsalva manoeuvre in 20 patients before and after spinal anaesthesia. The pulse oximeter waveform showed changes typical of the expected heart rate and pulse volume changes seen in each phase of the Valsalva manoeuvre. There were no significant changes in the typical pulse volume changes of the Valsalva manoeuvre after spinal anaesthesia, which achieved a sensory block ranging in upper extent from T_3*–*T_{12}*. There was, however, a significant delay in recovery of the pulse volume in phase 4 of the Valsalva manoeuvre after spinal anaesthesia from a mean(SD) of 3.1 (0.9) s to 6.2 (3.1) s* ($p < 0.05$)*. There was also a significant reduction in reflex bradycardia seen in phase 4. However, this was found only at 5, 10 and 15 min after spinal anaesthesia and was not associated with a significant change in Valsalva ratio or maximum-to-minimum rate ratio. The study confirms that the normal response to a standard Valsalva manoeuvre is suppressed only mildly during spinal anaesthesia in normovolaemic fit patients.*

Key words

Valsalva manoeuvre.
Anaesthetic techniques, regional; spinal.
Measurement techniques; pulse oximetry.

The cardiovascular effects of spinal anaesthesia by local anaesthetics are caused by a preganglionic sympathetic blockade. The extent of sympathetic blockade in relation to the sensory blockade, and its effect on cardiovascular reflexes, are areas of controversy [1, 2]. The differential sympathetic blockade measured indirectly by temperature elevation of the skin using thermographic imagery has been found to extend to an average of six segments above the upper level of sensory blockade [3]. These findings suggest that high sympathetic blockade occurs commonly during spinal anaesthesia.

The Valsalva manoeuvre is a practical test which depends on the integrity of a cardiovascular reflex mediated primarily by the autonomic nervous system [4, 5]. Pulse oximetry has been used to provide a rapid noninvasive measurement of finger tip blood flow showing the characteristic pulse volume and heart rate changes which follow a Valsalva manoeuvre [6].

This study was designed to evaluate the effect of spinal anaesthesia on the normal cardiovascular responses to the Valsalva manoeuvre as measured by continuous noninvasive pulse oximetry.

Methods

Twenty fit patients who received spinal anaesthesia for surgery below the umbilicus were studied. Informed consent and Ethics Committee approval were obtained. Patients who were taking antihypertensive drugs were not studied.

A Criticare 504-US pulse oximeter was attached to the index finger of the nondominant hand of each subject, who lay flat with the head on a pillow. A Valsalva manoeuvre was performed before spinal anaesthesia and at 5-min intervals for 20 min after spinal anaesthesia had been induced. The subject inspired to vital capacity and breathed out forcibly over 10 s through a calibrated valve which produced a slow blow-off at 4 kPa. The pressure was displayed on a simple Bourdon pressure gauge. Several practice manoeuvres were allowed before the study started.

Unlike some other pulse oximeters, the Criticare 504-US does not continually adjust the gain on the waveform output after it has been set. This unprocessed pulse waveform was recorded on a MSE-1400 chart recorder throughout each manoeuvre and for 20 s afterwards. The oximeter was active and connected throughout the test period.

Boluses of 250 ml of saline 0.9% were given in response to a decrease in systolic arterial pressure of greater than 20%; pressor agents were not required. Spinal anaesthesia was performed with the patient in the sitting position using a 25-gauge needle at L_{3-4} or L_{4-5}. The patients were returned to the supine position immediately after injection of heavy bupivacaine in a dose determined by the operation and patient characteristics. Arterial pressure, heart rate and

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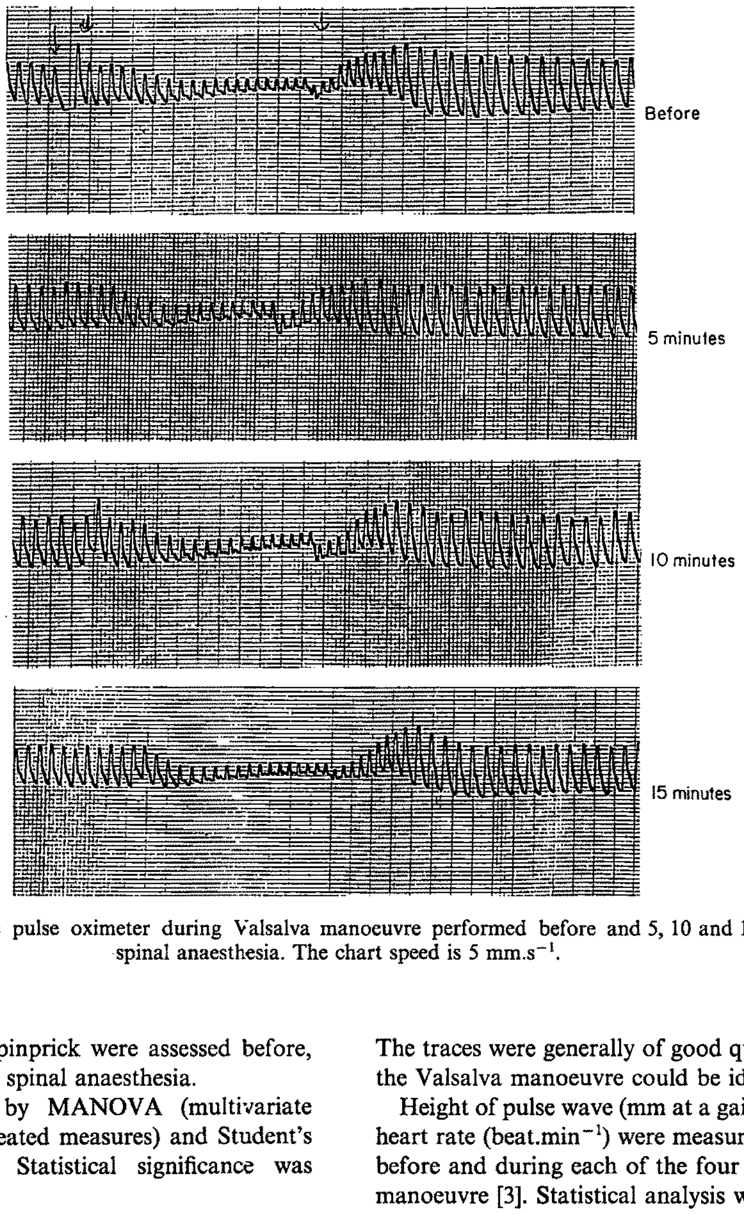

Fig. 1. Typical trace from the pulse oximeter during Valsalva manoeuvre performed before and 5, 10 and 15 min after induction of spinal anaesthesia. The chart speed is 5 mm.s^{-1}.

extent of sensory block to pinprick were assessed before, and at 5-min intervals after, spinal anaesthesia.

Statistical analysis was by MANOVA (multivariate analysis of variance for repeated measures) and Student's *t*-tests where appropriate. Statistical significance was assumed if $p < 0.05$.

Results

The results from 18 patients were analysed; two patients were unable to perform a Valsalva manoeuvre. The mean (SD) age was 47 (14) years. The median upper level of sensory block was $T_{9.5}$ (range T_3–T_{12}). The mean (SD) dose of bupivacaine was 14.2 (1.3) mg.

Figure 1 shows typical chart recordings during standard Valsalva manoeuvres before and after spinal anaesthesia. The traces were generally of good quality and all phases of the Valsalva manoeuvre could be identified easily.

Height of pulse wave (mm at a gain of 50 mV.mm^{-1}) and heart rate (beat.min^{-1}) were measured from the recordings before and during each of the four phases of the Valsalva manoeuvre [3]. Statistical analysis was applied to the total group (TG) ($n = 18$) and two subgroups: those with a sensory block to T_9 or above (high block group; HBG) ($n = 9$); and those with a sensory block below T_9 (low block group, LBG) ($n = 9$). The median height of sensory block in the HBG was T_7 (range T_3 to T_9) and in the LBG T_{10} (range T_{10}–T_{12}).

The voltages of the pulse oximeter waveform during the four phases of the Valsalva manoeuvre are shown in Table 1 as a percentage of the pre-Valsalva voltage. There was no significant difference in the percentage change of the pulse

Table 1. The change in voltage of the pulse waveform during the four phases of the Valsalva manoeuvre as a percentage of the pre-Valsalva voltage in patients ($n = 18$) undergoing spinal anaesthesia as measured using the waveform output of a Criticare pulse oximeter. Results are expressed as mean (SD) percentage change from baseline.

Time after spinal block	Phase 1	Phase 2	Phase 3	Phase 4
0	7.5 (18.3)	−50.7 (17.0)	−54.3 (18.2)	28.0 (21.2)
5	8.8 (17.6)	−55.1 (17.3)	−56.8 (20.3)	13.8 (17.3)
10	8.4 (13.7)	−55.8 (24.4)	−59.1 (28.9)	21.7 (27.6)
15	2.7 (11.8)	−54.3 (17.5)	−58.4 (19.5)	22.7 (32.4)
20	3.6 (11.8)	−54.5 (12.4)	−58.6 (10.3)	15.1 (18.8)

Table 2. Derived indices from the Valsalva manoeuvre in patients ($n = 18$) undergoing spinal anaesthesia. Data are presented as mean SD.

Time after spinal block	Time to recovery (s)	Ratio of pulse volumes		Heart rate	
		phase 3/0	phase 4/0	Max/min	4/0 change
0 min	3.1 (0.9)	0.5 (0.2)	1.2 (0.2)	1.40 (0.27)	−13.1 (14.4)
5 min	4.4 (2.4)	0.5 (0.2)	1.2 (0.2)	1.32 (0.25)	−2.4 (15.7)*
10 min	4.0 (1.8)	0.4 (0.3)	1.2 (0.3)	1.31 (0.25)	−0.9 (16.2)*
15 min	5.3 (3.2)	0.5 (0.2)	1.2 (0.3)	1.27 (0.23)	−1.8 (20.6)*
20 min	6.2 (3.1)	0.5 (0.1)	1.2 (0.2)	1.40 (0.20)	−10.6 (17.6)
†	$p<0.05$	NS	NS	NS	NS

*$p<0.05$ versus prespinal heart rate change (*t*-test).

†Significance by MANOVA (repeated measures) of time 0 versus time 5, 10, 15 and 20 min.

Table 3. Mean (SD) heart rate (beats.min^{-1}) during the different phases of Valsalva manoeuvre in patients ($n = 18$) undergoing spinal anaesthesia.

Time after spinal block min	Valsalva phase				
	Pre	Phase 1	Phase 2	Phase 3	Phase 4
0	98.9 (20.5)	88.1 (20.7)	111.3 (22.8)	117.2 (22.1)	85.9 (17.8)
5	95.9 (17.8)	86.7 (15.1)	112.6 (22.9)	120.6 (21.5)	93.5 (19.7)
10	94.3 (15.4)	86.3 (16.6)	110.3 (22.8)	119.3 (24.2)	93.4 (22.1)
15	96.3 (15.3)	87.4 (17.8)	109.1 (21.7)	117.6 (19.1)	94.5 (22.4)
20	92.2 (13.5)	81.5 (13.7)	109.0 (22.0)	114.8 (19.6)	83.4 (16.5)

Table 4. Mean (SD) time to recovery (s) and the ratio of maximum to minimum heart rates (beat.min^{-1}) during the Valsalva manoeuvre in patients with a high sensory block ($n=9$) or a low sensory block ($n=9$) after spinal anaesthesia.

Time after spinal block min	Time to recovery		Max/min heart rate	
	High block	Low block	High block	Low block
0	3.0 (1.0)	3.1 (0.9)	1.41 (0.26)	1.38 (0.28)
5	4.2 (2.6)	4.6 (2.4)	1.34 (0.30)	1.29 (0.18)
10	4.0 (1.7)	4.1 (2.1)	1.28 (0.17)	1.33 (0.31)
15	5.2 (2.3)	5.3 (4.2)	1.22 (0.22)	1.33 (0.21)
20	6.2 (2.5)	6.3 (3.8)	1.44 (0.26)	1.45 (0.37)
*	$p<0.05$	NS	NS	NS

*Significance measured by MANOVA (repeated measures) of time 0 versus time 5, 10, 15 and 20 min.

volume when prespinal Valsalva manoeuvres were compared with those performed after spinal anaesthesia. The ratios of pulse volume in phase 3 and phase 4 to pre-Valsalva control did not change significantly after spinal anaesthesia at any time (Table 2).

The heart rate changes are shown in Table 3. The maximum heart rate divided by minimum heart rate (Valsalva ratio [6]) was calculated; no significant change was found after spinal anaesthesia (Table 4). The change in heart rate from pre-Valsalva to phase 4 was calculated. A significant reduction in the decrease in heart rate associated with phase 4 was found at 5, 10 and 15 min after spinal anaesthesia; this change was not significant at 20 min (Table 2).

The time taken for the pulse volume to return to the pre-Valsalva amplitude was calculated. There was a significant delay in recovery from 3.1 (0.9) to 6.2 (3.1) s in the TG after spinal anaesthesia ($p < 0.05$); the delay was significant in the HBG, but not in the LBG (Table 4).

The maximum percentage decrease in systolic blood pressure was a mean (SD) of 11.4 (8.1)%, at 15 min. This decrease was statistically significant.

No postspinal headaches were discovered on follow-up of patients on the first postoperative day.

Discussion

The Valsalva manoeuvre requires patient cooperation and 10% of our study group were unable to perform the manoeuvre to our satisfaction. The Valsalva manoeuvre has been shown to be reproducible and has been used clinically as a screening test for cardiac disease [7] and diabetic neuropathy [8].

We found the Criticare oximeter to be a very effective, noninvasive tool for recording the changes in pulse volume and rate associated with the Valsalva manoeuvre. The Valsalva ratio could be calculated easily by dividing the maximum peak-to-peak interval by the minimum peak-to-peak interval. The waveform output displayed all the typical changes of the Valsalva manoeuvre and we have assumed that the pulse oximeter measures finger blood flow, and thus pulse volume indirectly.

The Valsalva manoeuvre can be divided into four phases [4]. Phase 1 occurs at the onset of the strain and results in transient increases in blood pressure and pulse pressure. In phase 2, increased intrathoracic pressure limits venous return, the pulmonary reservoir is depleted and cardiac return is inadequate, resulting in steady decreases in blood pressure and pulse pressure. Typically this response is associated with tachycardia and peripheral vasoconstriction, which limits the decrease. In phase 3 the strain is released and this results in a transient further decrease in blood pressure and pulse volume. In phase 4, a rapid improvement in venous return occurs, resulting in improved blood pressure and pulse volume. There is an overshoot in blood pressure and pulse volume with a resultant reflex bradycardia. Phases 1 and 3 are thought to be the result of mechanical effects of forced expiration while phases 2 and 4 are thought to be the effect of autonomic circulatory reflexes.

Patients with cardiovascular disease display an abnormal response to the Valsalva manoeuvre. The abnormal 'square wave' response is characterised by failure of the pulse pressure to decrease significantly during the strain period and by the absence of overshoot. The typical rate changes are reduced or absent and the Valsalva ratio is decreased [5–7].

Normal circulatory responses to posture, blood loss, positive pressure ventilation and the Valsalva manoeuvre are mediated by the autonomic nervous system. Individuals with autonomic dysfunction as found in diabetes mellitus [8], tabes dorsalis [9] and treated hypertension may exhibit abnormal responses to the Valsalva manoeuvre. A typical response to the Valsalva manoeuvre in patients with autonomic dysfunction is an exaggerated fall in pulse pressure with a slow recovery after release of straining, with loss of the typical phase 4 overshoot. The usual heart rate changes are absent, with a reduced Valsalva ratio [8].

The normal reflex responses of pulse volume to the Valsalva manoeuvre after spinal anaesthesia were well preserved even in patients with a sensory block up to midthoracic dermatomes. Some evidence of suppression of circulatory responses was found in that there was a significant reduction in reflex bradycardia at 5, 10 and 15 min. However, the pulse volume changes were well preserved and there were no significant changes in Valsalva ratio, or the ratio of phase 2 and phase 4 to control pulse volumes; thus there was evidence of only mild suppression of the circulatory responses to the Valsalva manoeuvre. Spinal anaesthesia did not result in a fall in pulse volume in the upper limb, as measured by pulse oximetry. There was a significant delay in recovery of pulse volume in phase 4 following spinal anaesthesia in the HBG. This was not associated with any change in Valsalva ratio and so is most likely to be due to reduced venous return secondary to peripheral vasodilatation. Spinal anaesthesia was generally well tolerated, as shown by the mild reduction in the average systolic blood pressure (11.4%).

The zone of differential sympathetic blockade or sympathetic-to-sensory block height difference as measured by the ability to appreciate the sensation of cold has been shown to occupy an average of two spinal segments, but up to six segments in some patients during hyperbaric amethocaine anaesthesia [10]. More recently, Chamberlain and Chamberlain found an average differential sympathetic blockade of six segments as measured by elevation in trunk skin temperature using thermographic imagery [3]. Such a degree of differential blockade implies that many patients in the present study, especially in the high block group where the mean sensory block was to spinal segment T_7, had a sympathetic block high enough to affect sympathetic cardiac efferents which originate from segments T_1–T_4.

Our results support the findings of Takeshima and Dohi, who found that high level sympathectomy by cervical epidural blockade depresses reflex circulatory responses only partly in young healthy humans [11]. Weaver, Pearson and Rosen also found no significant change in the Valsalva response after epidural blockade to T_8 in pregnant women [12].

Thus there seems to be preservation of the cardiovascular reflex demonstrated by the Valsalva response even in patients with high epidural or spinal blockade. The clinical impression that normovolaemic subjects usually tolerate midthoracic sensory spinal blockade would support this finding. Several theories have been proposed to explain this. Firstly, the sympathetic blockade at higher levels, as displayed by cutaneous temperature changes, may represent only partial blockade. Secondly, many of the heart rate changes may be linked to a reflex independent of sympathetic or vagal innervation, such as that mediated by atrial chronotropic stretch receptors [1]. Finally, blockade of cardiac sympathetic fibres still leaves parasympathetic control intact and these may contribute to the cardiac circulatory reflex.

The Criticare 504-US pulse oximeter was found to be an effective tool for measuring the response to the Valsalva manoeuvre in patients undergoing spinal anaesthesia. However, since there was little change in the Valsalva response, we conclude that the Valsalva manoeuvre does not provide a sensitive test for the assessment of the cardiovascular consequences of sympathetic blockade during spinal anaesthesia.

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The response times during anaesthesia of pulse oximeters measuring oxygen saturations during hypoxaemic events

I. J. BROOME, R. W. HARRIS AND C. S. REILLY

Summary

Episodes of desaturation were recorded simultaneously by computer from two Ohmeda Biox 3700 pulse oximeters, one with an ear and one with a finger probe, on patients undergoing anaesthesia. Over a period of 6 months, 28 episodes of desaturation were detected. Analysis of the recordings showed the mean minimum saturations recorded for ear and finger probes were 86.3% and 83.5% respectively ($p < 0.01$). The mean delay for finger compared to ear pulse oximetry was 4.4 s ($p < 0.01$). Analysis at different saturation levels showed finger probe responses to be significantly slower than ear probe responses at saturations equal to and above 91% ($p < 0.05$). At saturation levels of 90% or less no significant difference in probe response times were found.

Key words

Equipment; pulse oximeter.
Measurement techniques.

Pulse oximeters are widely regarded as instruments which provide a measurement of oxygen saturation throughout the body. This may be true in the steady state, but under dynamic conditions pulse oximetry only gives an accurate assessment of saturation at the point of measurement. When Severinghaus [1] induced decreases in arterial oxygen tension in normal subjects he found response delays of up to 50 s and 10 s for saturation readings obtained from pulse oximeter probes placed on the finger and earlobe respectively.

The aim of this investigation was to see if such profound delays in finger probe response occur in patients during hypoxaemic events during anaesthesia.

Methods

Following Ethics Committee approval, apparatus capable of detecting and recording episodes of desaturation using two pulse oximeters, one with a finger and one with an ear probe was used in the operating theatre suite for a period of 6 months.

The apparatus consisted of two Ohmeda Biox 3700 pulse oximeters (both software revision R and with averaging times set to 6 s) connected via their analogue output to a BBC B microcomputer which ran a programme written to detect and record hypoxaemic events. The programme formed a continuously updated, minute long, memory loop of saturation readings taken simultaneously from both pulse oximeters every 0.5 s. If the saturation reading of either pulse oximeter fell below 93% the saturation readings from both were recorded on to a computer disc for a period which started 1 min before the onset of desaturation and lasted until 1 min after ear and finger saturations returned to normal. The numerical display of both oximeters were covered so that they did not influence the course of the anaesthetic, although the audible alarms, which went off at a saturation reading of 90%, were not disabled in order to provide additional patient safety. The anaesthetist administering the anaesthetic was free to give any relevent treatment to prevent or correct episodes of desaturation.

The pulse oximeter probes and connections to the computer were changed at weekly intervals.

Statistical analysis

Events were analysed by relating the times at which ear and finger saturation readings occurred to the time at which the saturation reading from the ear first fell to 93%. The mean times at which different saturation levels were reached by

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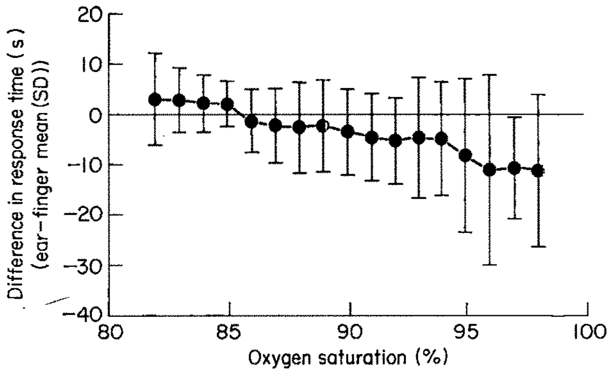

Fig. 1. The difference in response time of oximeters measuring saturation at the finger and at the ear against oxygen saturation.

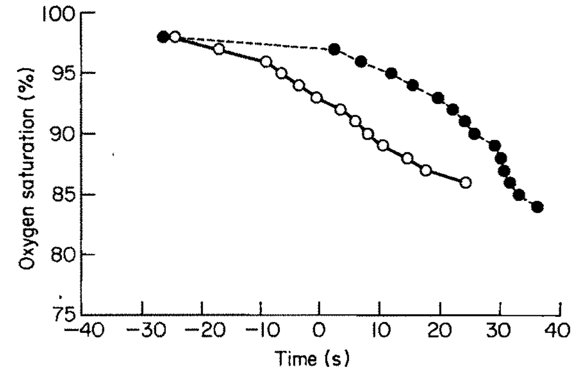

Fig. 2. Oxygen saturation plotted against time for ear (○) and finger (●) pulse oximetry showing the most extreme example of finger pulse oximeter delay recorded during the study.

both pulse oximeters were compared using paired *t*- and signed-rank tests.

Results

During the study period 28 hypoxaemic events were recorded in 11 males and 17 females ranging from 22 to 74 years of age.

Analysis of the recordings showed that the overall mean delay for finger compared to ear pulse oximetry was 4.4 s ($p < 0.01$). Analysis at different saturation levels showed finger probe responses to be significantly slower than the ear probe at saturations equal to and above 91% ($p < 0.05$), but probe response times were not significantly different below this figure (Fig. 1).

No significant difference was found between the mean saturations recorded from the two probes before desaturation events occurred (Table 1). However, the mean minimum saturation recorded at the finger (83.5%) was significantly lower ($p < 0.01$) than that found when measuring saturation at the ear (86.3%).

Fugure 2 shows the most extreme case of finger probe delay recorded.

Discussion

We found that there was an overall delay in the detection of hypoxia using finger as opposed to ear pulse oximetry of 4.4 s. However, we also found that this delay was due to an initial slow response of finger pulse oximetry. At saturations of 90% or less we were unable to demonstrate any significant difference between ear and finger probe response times. The mean minimum saturation measured at the finger was significantly lower than that measured at the ear.

Ear probe recordings show a gradual slow fall in saturation which starts early in the course of a desaturation event. Finger probes show a delayed onset of response, probably caused by the longer circulation time to the finger compared to the ear. However, once finger saturations fall they do so rapidly, catching up with falls in ear saturations at a saturation level of 90% and they continue to fall when the ear probe has stopped. The reason for this is unclear, but it is unlikely that it is due to an actual difference in arterial oxygen saturation at the two points. Experimentally induced hypoxia has been shown to produce this same effect, with both ear and radial arterial values reading higher than finger saturations [1]. We feel it is more likely that the effect is due to interference caused by desaturated capillary and venous blood [2]. A pulse oximeter estimates arterial oxygen saturation by electronically resolving the output from each of its photodiodes, into both alternating current (which detects absorption due to the pulsating component of the tissues, e.g. arterial blood vessels) and direct current (which detects absorption due to nonarterial blood and tissue) [3]. The direct current component of the signal should be totally excluded from further processing that produces values which represent arterial oxygen saturation. However, the presence of nail polish [4] or skin dyes [5] can affect the accuracy of finger pulse oximetry and so the presence of markedly desaturated venous blood in areas of low blood flow per unit mass could account for the lower saturation readings seen using finger pulse oximetry. Although the mean delay for finger pulse oximeters was 4.4 s compared to the ear, the most extreme delay was 17.5 s. This is similar to 40 s delay recorded on volunteers [1]. Long instrument averaging times and any factors which impair the flow of blood to the tissues onto which the sensor is placed [6] are likely to further increase these delays.

Table 1. The mean maximum and minimum (SD) saturations recorded at the ear and finger.

	Ear saturation	Finger saturation	
Mean maximum saturation	96.2% (1.5)	96.6% (1.8)	$p < 0.13$
Mean minimum saturation	86.3% (3.7)	83.5% (4.2)	$p < 0.01$

A computer model of the cardiorespiratory system [7] has been used in an attempt to assess the significance that these time delays would have on the detection of hypoxic events. Various causes of oxygen supply failure were examined and arterial oxygen saturation fell most rapidly where ventilation with a gas mixture contained no oxygen. It was shown that severe brain hypoxia could occur before a pulse oximeter, with a detection delay of 60 s, would alarm.

Other workers have investigated pulse oximeter response delays using different sensor sites [8] but did not compare delays in actual clinical situations using two pulse oximeters of identical specification. The differences in delay times and saturation recordings that we detected are likely to be due to actual differences in the characteristics of blood flow to the subject's ear and finger.

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Effect of fentanyl on the circulatory responses to orotracheal fibreoptic intubation

J. E. SMITH, M. J. KING, H. F. YANNY, K. A. POTTINGER AND M. B. POMIRSKA

Summary

The effectiveness of fentanyl in attenuating the pressor and heart rate response to orotracheal fibreoptic intubation under general anaesthesia was assessed in 60 healthy patients undergoing elective surgery. Patients were randomly assigned to receive either fibreoptic intubation with or without fentanyl 6μg.kg^{-1} or traditional Macintosh intubation with fentanyl 6μg.kg^{-1}. A standardised general anaesthetic was administered which included temazepam premedication, thiopentone, atracurium, oxygen, nitrous oxide and isoflurane. The pressor response to fibreoptic intubation was suppressed in those patients who received fentanyl and was similar to that seen in the Macintosh–fentanyl group of patients. The heart rate response to fibreoptic intubation was also significantly reduced in the patients who received fentanyl, but, in contrast, was still significantly greater than that in the Macintosh–fentanyl group. Fentanyl 6μg.kg^{-1} appears to have a useful place in attenuating the cardiovascular effects of fibreoptic intubation under general anaesthesia.

Key words

Anaesthesia; general.
Intubation, tracheal; complications.
Equipment; fibreoptic laryngoscope.
Analgesics, narcotic; fentanyl.

Tracheal intubation under general anaesthesia, facilitated by the Macintosh laryngoscope, produces a marked pressor and heart rate response which may be particularly hazardous for patients with cardiovascular disease. Consequently, many methods of attenuating these responses have been investigated [1] and fentanyl has been identified as an effective agent in this regard [2, 3]. It has recently been shown that fibreoptic-assisted orotracheal intubation produces significantly greater cardiovascular effects than Macintosh intubation [4, 5]. It is therefore important to establish whether fentanyl is as effective in controlling the responses to this type of intubation as it is in controlling the responses to traditional intubation. This study was therefore designed to compare the arterial pressure and heart rate changes during fibreoptic tracheal intubation with and without fentanyl with those of Macintosh intubation with fentanyl.

Methods

The investigation was approved by the Ethics Committee of the South Birmingham Health Authority and informed written consent was obtained from each patient. Sixty healthy (ASA class 1) patients, aged between 16 and 55 years, undergoing elective gynaecological, general or ear, nose and throat surgery requiring tracheal intubation and mechanical ventilation of the lungs, were studied. Patients taking vasoactive drugs, the morbidly obese, those with a history of acid reflux or hiatus hernia and those in whom difficult intubation was expected were excluded from the study.

Patients were premedicated 1 h before surgery with temazepam 20 mg orally. On arrival in the anaesthetic room, an indwelling intravenous cannula was sited and continuous electrocardiographic (ECG) monitoring was established. A Dinamap pulse oximeter was used to measure arterial oxygen saturation and heart rate continuously and a Dinamap 1846SX automatic oscillometer was used to measure arterial pressure at 1 min intervals. Readings were recorded with a Dinamap TR2000 printer. Any patients with a resting arterial pressure above 150/90 mmHg took no further part in the study. After a stabilisation period of at least 5 min, baseline recordings were made and anaesthesia was induced with thiopentone 5 mg.kg^{-1}, followed

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by atracurium 0.5 mg.kg^{-1}. The patient's lungs were ventilated for 4 min with oxygen 50%, nitrous oxide 50% and isoflurane 1% by means of a Guedel airway and facemask attached to a Bain system with an initial fresh gas flow of 90 ml.kg^{-1}.min^{-1}. Carbon dioxide concentration was monitored with a Nellcor N-1000 capnograph and fresh gas flow and ventilation were adjusted to maintain the end-expired carbon dioxide concentration at 4.5–5%. Patients were assigned, on a random number basis (stratified by sex, using sealed envelopes), to one of three groups. Patients allocated to the Macintosh–fentanyl group received fentanyl 6 μg.kg^{-1} after 2 min facemask ventilation, followed by traditional intubation 2 min later. Patients allocated to the fibreoptic–saline group received 0.1 ml.kg^{-1} 0.9% saline followed by fibreoptic intubation with an Olympus LF-1 fibreoptic laryngoscope, and patients in the fibreoptic–fentanyl group received fentanyl 6μg.kg^{-1} followed by fibreoptic intubation. The tongue traction method of fibreoptic intubation was used as has been described previously [4, 6]. The Dinamap oscillometer was switched to standby mode while the appropriate intubation was performed, and as soon as tracheal placement of the tube was confirmed by capnography, an arterial pressure determination was initiated and four further recordings were obtained at 1 min intervals. The intubation time was taken as the interval between removal of the facemask from the patient's face and reconnection of the Bain system to the catheter mount after intubation had been completed. If any intubation could not be completed within 60 s, the patient was withdrawn from the trial and his/her assignment card was resealed in an envelope and randomly placed among the remaining envelopes to be used later.

Data were analysed using Student's paired *t*-test (within groups) and analysis of variance (between groups); $p < 0.05$ was deemed significant.

Results

The three groups were similar with respect to age, weight and sex (Table 1).

Table 1. Age, weight and sex characteristics. Data expressed as mean (SEM) where applicable.

Group	Age; years	Weight; kg	Sex
Fibreoptic–fentanyl ($n = 20$)	42.9 (1.7)	72.4 (2.8)	5M 15F
Fibreoptic–saline ($n = 20$)	37.9 (2.1)	70.6 (3.0)	5M 15F
Macintosh–fentanyl ($n = 20$)	36.4 (2.6)	65.1 (1.4)	5M 15F

Table 2. Time to achieve successful intubation.

Group	Number	Mean (SEM) time; seconds	Range; seconds
Fibreoptic–fentanyl	20	36.7 (2.8)*	25–50
Fibreoptic-saline	20	39.7 (3.0)*	25–55
Macintosh–fentanyl	20	16.4 (1.4)	8–40

*$p < 0.05$ compared with Macintosh intubations.

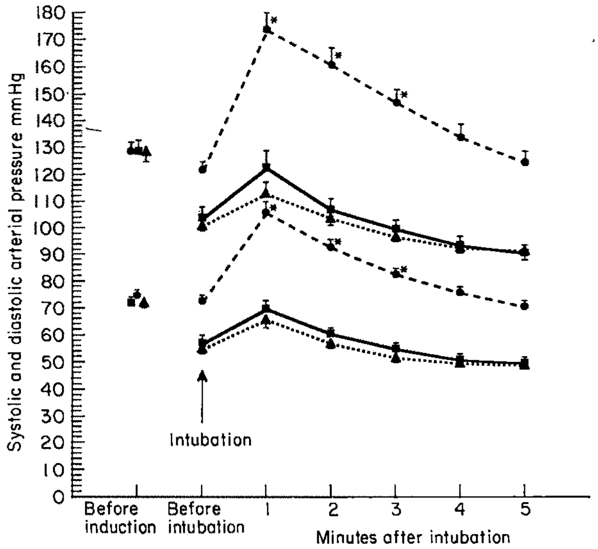

Fig. 1. Mean (SEM) systolic and diastolic arterial pressures, in each group before induction of anaesthesia, before intubation and for 5 min after intubation. ——, fibreoptic–fentanyl group; - - - -, fibreoptic–saline group; ··········, Macintosh–fentanyl group. *Significant increase compared with values before induction ($p < 0.05$).

One intubation in the fibreoptic–saline group could not be completed within 60 s, so the lungs were reventilated with a facemask and anaesthetic circuit and tracheal intubation was performed uneventfully with the Macintosh laryngoscope. The mean times required to achieve successful intubations in the fibreoptic groups were significantly greater than those required for Macintosh intubation (Table 2). There was no significant difference between the mean intubation times of the two fibreoptic groups.

The mean changes in arterial pressures and heart rates within the three groups are summarised in Figures 1 and 2. Arterial pressures in the fibreoptic–saline group were significantly greater after intubation compared with values

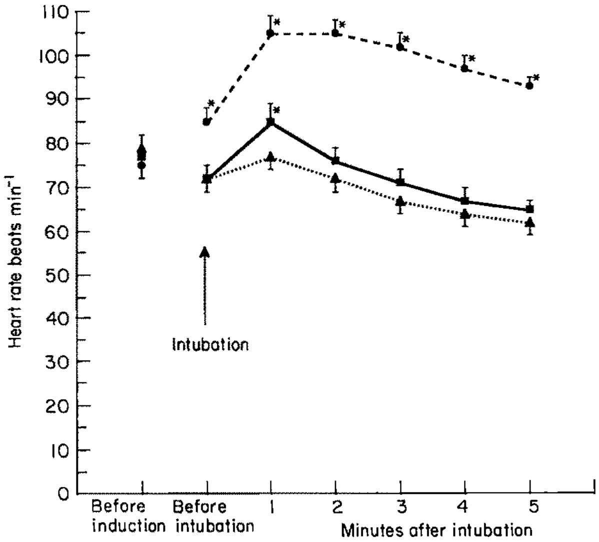

Fig. 2. Mean (SEM) heart rates in each group before induction of anaesthesia, before intubation and for 5 min after intubation. ——, fibreoptic–fentanyl group; - - - -, fibreoptic–saline group; ··········, Macintosh–fentanyl group. *Significant increase compared to pre-induction values ($p < 0.05$).

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before induction. However, arterial pressures in both fentanyl groups after intubation were similar to or lower than baseline values. Mean heart rates in the fibreoptic–saline group were significantly greater than values before induction during all 5 postintubation minutes. Mean heart rates in the Macintosh–fentanyl group after intubation were similar to or lower than values before induction. The mean heart rate during the first minute after intubation in the fibreoptic–fentanyl group was significantly greater than the baseline value.

Analysis of variance revealed that there were no significant differences between the three groups before induction of anaesthesia. After induction but before intubation there were significant differences between the fibreoptic–saline group and the other two groups, with regard to both arterial pressure and heart rate. After intubation, the arterial pressure in the fibreoptic–saline group was significantly greater than in the other two groups, but there was no significant difference between the fibreoptic–fentanyl and the Macintosh–fentanyl groups. After intubation, the heart rate in the fibreoptic–saline group was significantly greater than in the other two groups and the heart rate in the fibreoptic–fentanyl group was significantly greater than that in the Macintosh–fentanyl group.

Discussion

The fibreoptic laryngoscope can provide an elegant solution to many airway management problems by affording its exponents an opportunity to secure tracheal intubation when traditional methods fail [6, 7]. As interest in the application of fibreoptics to anaesthetic practice has increased, so too has interest in the haemodynamic effects of fibreoptic techniques, in both awake and anaesthetised patients.

Ovassapian and colleagues [8] considered that the heart rate and arterial pressure changes during fibreoptic nasal intubation in awake but sedated patients under local anaesthesia were small and likely to be less than those associated with rigid laryngoscopy. However, when Schrader and colleagues [9] compared awake oral fibreoptic intubation directly with awake oral rigid intubation, there were no clear differences between the responses to the two techniques, although the rigid intubation group did show a significant increase in mean arterial pressure not seen in the fibreoptic group. Hawkyard and colleagues [10] found that awake nasal fibreoptic intubation caused remarkably little cardiovascular disturbance in comparison with traditional intubation under thiopentone/suxamethonium anaesthesia. Randell and colleagues [11] demonstrated that the addition of alfentanil to the sedation–local anaesthesia sequence during nasal fibreoptic intubation improved intubating conditions and significantly reduced the pressor and heart rate response.

Smith and colleagues [4, 5] studied the responses to oral fibreoptic intubation under general anaesthesia. They found significantly greater heart rate and arterial pressure increases in the fibreoptic intubation groups than in the Macintosh intubation groups, whether the tongue traction or Berman airway method of fibreoptic intubation was used. Finfer and colleagues [12], in a similar trial, found a significantly higher heart rate in the fibreoptic group, but did not detect significant differences between the fibreoptic and Macintosh groups with regard to arterial pressure, although both groups exhibited significant increases in arterial pressures above pre-induction levels. The discrepancies between these investigations may be accounted for by differences in the anaesthetic techniques and cardiovascular monitoring used. Smith *et al.* used halothane 0.5% as the inhalational agent, whereas Finfer *et al.* used enflurane 2% and either intramuscular papaveretum 0.2–0.3 $mg.kg^{-1}$ or intravenous fentanyl 0.1 mg; it is possible that pressor responses may have been partially attenuated by the latter technique. However, Finfer and coworkers did not specify the precise method of fibreoptic intubation studied and although a pulse oximeter was used to measure heart rate, an anaeroid sphygmomanometer was used to measure arterial pressure changes; it is conceivable that this device was not sufficiently accurate to identify relatively subtle differences between the two groups. Smith and colleagues [13] also investigated the effects of nasotracheal fibreoptic intubation in patients under general anaesthesia and found a significantly smaller rise in arterial pressure during the first minute after intubation in the fibreoptic group, but once again a significantly greater tachycardia in the fibreoptic group compared with the Macintosh group. Schaefer and Marsch [14] have recently reported that a total intravenous technique using a continuous infusion of propofol plus a bolus of fentanyl (0.1 or 0.2 mg) was successful in abolishing both the arterial pressure and heart rate responses to fibreoptic and Macintosh oral intubation.

This investigation has shown that fentanyl 6 $\mu g.kg^{-1}$ suppresses the hypertensive response to fibreoptic intubation as effectively as it does to Macintosh intubation. It also substantially attenuates the tachycardia associated with fibreoptic intubation. The heart rate during fibreoptic–fentanyl intubation was significantly greater than that during Macintosh–fentanyl intubation and during the first minute after intubation was significantly greater than heart rate before induction. However, the increase in mean heart rate was no more than 8 $beat.min^{-1}$, so although of statistical significance, this rise is probably of little clinical importance. Hence, fentanyl 6$\mu g.kg^{-1}$ can be recommended as a simple and effective method of minimising the cardiovascular disturbances produced by orotracheal fibrescope-guided intubation under general anaesthesia.

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We gratefully acknowledge the help and support given by medical, nursing and operating department assistant staff at Selly Oak Hospital. We also thank the following companies who generously provided the equipment used in this trial: KeyMed UK (Olympus LF-1 fibreoptic laryngoscope), Critikon UK (Dinamap 1846SX monitor and TR2000 printer) and Nellcor Europe BV (Nellcor N-1000 monitor).

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Effects of nicardipine on the circulatory responses to tracheal intubation in normotensive and hypertensive patients

K. OMOTE, A. KIRITA, A. NAMIKI AND H. IWASAKI

Summary

This study was undertaken to examine the effects of nicardipine on circulatory responses to laryngoscopy and tracheal intubation in normotensive ($n = 39$) and hypertensive ($n = 36$) patients. Laryngoscopy and tracheal intubation were performed after induction of anaesthesia with thiamylal, followed by administration of intravenous saline or nicardipine 20 or 30 $\mu g.kg^{-1}$ and suxamethonium. Blood pressure and heart rate were recorded, and rate-pressure product was calculated. Nicardipine 20 and 30 $\mu g.kg^{-1}$ prevented the increase in mean arterial pressure after intubation in normotensive and hypertensive patients ($p < 0.01$ compared with saline). The changes in heart rate after intubation were significantly greater in normotensive patients than in hypertensive patients when 20 or 30 $\mu g.kg^{-1}$ of nicardipine was given ($p < 0.05$ and $p < 0.01$ respectively). Rate-pressure product increased significantly ($p < 0.01$) after intubation in normotensive patients whether nicardipine was administered or not, but the increase was suppressed completely by nicardipine 20 or 30 $\mu g.kg^{-1}$ in hypertensive patients. We conclude that nicardipine is effective in preventing the circulatory responses to laryngoscopy and tracheal intubation in hypertensive patients.

Key words

Intubation, tracheal; complications.
Blood pressure; hypertension.
Pharmacology; calcium channel blockers, nicardipine.

Laryngoscopy and tracheal intubation after induction of anaesthesia are associated with transient hypertension and tachycardia, and many methods of attenuating the circulatory responses to intubation have been studied [1–9].

Hypertensive patients are more prone to significant increases in blood pressure following laryngoscopy and tracheal intubation whether they have been treated beforehand or not [6]. Fox *et al.* [10] reported two hypertensive patients in whom complications, including pulmonary oedema and rupture of cerebral aneurysm, followed a hypertensive episode related directly to laryngoscopy and tracheal intubation. Transient hypertension and tachycardia are probably of little consequence in healthy individuals, but either or both may be hazardous to those with hypertension, myocardial insufficiency, or cerebrovascular disease.

Nicardipine is a new dihydropyridine derivative which acts as a calcium channel blocker. It is photoresistant and water soluble [11–13]. Nicardipine produces an immediate, short-acting and reliable reduction in blood pressure without provoking adverse effects such as hypotension, disturbances of atrioventricular conduction and myocardial depression [12,14]. Moreover, it shows consistent augmentation of coronary blood flow, oxygen delivery and aerobic metabolism in ischaemic myocardium [15–19]. These properties make nicardipine a potentially attractive drug for the prevention of circulatory responses to laryngoscopy and tracheal intubation in hypertensive patients as well as in normotensive patients, and the present study was designed to evaluate its use in these situations.

Methods

The study was approved by the Ethics Committee in our Institute and informed consent was obtained from each patient. Thirty-nine normotensive patients (ASA class 1) aged between 37 and 68 years and 36 hypertensive patients (ASA class 2) aged between 39 and 75 years were studied. Hypertension was diagnosed if systolic blood pressure exceeded 160 mmHg and/or diastolic blood pressure was greater than 95 mmHg (as defined by the World Health Organisation). All hypertensive patients were already receiving oral medication of a calcium antagonist (nifedipine, nicardipine or diltiazem), or enalapril or metoprolol daily, and received their medication 6 h before induction of anaesthesia.

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Table 1. Data relating to normotensive and hypertensive patients. Data represent mean (SD).

Dose (μg.kg^{-1})	*n*	Sex (M:F)	Age (years)	Body weight (kg)	Height (cm)
Normotensive patients					
0	13	8:5	51.2 (6.7)	59.6 (11.9)	157.9 (7.8)
20	13	7:6	51.9 (4.6)	57.1 (6.3)	158.5 (6.6)
30	13	7:6	52.3 (8.9)	58.6 (9.2)	159.2 (6.3)
Total	39	22:17	51.8 (7.0)	58.5 (9.6)	158.9 (7.4)
Hypertensive patients					
0	10	5:5	58.0 (9.8)	60.5 (9.3)	157.8 (7.0)
20	13	7:6	59.7 (8.0)	58.8 (9.6)	153.1 (8.6)
30	13	7:6	58.2 (9.4)	57.5 (8.5)	158.1 (9.2)
Total	36	19:17	58.7 (9.2)*	58.8 (9.2)	156.2 (8.7)

*$p < 0.05$ compared with normotensive patients.

All patients had a normal electrocardiogram (ECG) on admission to hospital.

Premedication was with intramuscular midazolam 5 mg and atropine 0.5 mg 1 h before induction of anaesthesia. On arrival in the operating room, a 16-gauge intravenous cannula was inserted for infusion of Ringer lactate solution, and a blood pressure cuff and standard lead II ECG electrodes were applied.

Anaesthesia was induced with intravenous thiamylal 5 mg.kg^{-1}; loss of eyelash reflex and the response to verbal command were ensured. Then, in a double-blind fashion, normal saline, or nicardipine 20 μg.kg^{-1} or 30 μg.kg^{-1} was administered intravenously followed by suxamethonium 1.5 mg.kg^{-1}. Direct laryngoscopy for tracheal intubation was initiated 1 min after administration of suxamethonium.

Each intubation was performed by the first or second author and was accomplished within 20 s. No patient received topical or intravenous lignocaine before placement of the tracheal tube. After tracheal intubation, ventilation was controlled with 66% nitrous oxide in oxygen for 3 min; then enflurane (0.5–1%) was added.

Baseline values of blood pressure and heart rate were recorded before thiamylal administration. The next measurements were taken before intubation, after the cuff of the tracheal tube was inflated, and 1, 2 and 3 min after tracheal intubation. The rate-pressure product (RPP) was calculated by multiplying the systolic blood pressure by the heart rate.

All data were analysed using analysis of variance (ANOVA), followed by Student's *t*-test. A p value of less than 0.05 was taken to be statistically significant.

Results

Table 1 displays the demographic data. The hypertensive patients were receiving nifedipine (13 patients), nicardipine (10), diltiazem (6), enalapril (4) or metoprolol (3). No patient had a history of angina or congestive heart failure.

In the normotensive patients (Table 2), baseline values of mean arterial pressure (MAP), heart rate (HR) and RPP were comparable in patients who received saline, or nicardipine. MAP decreased significantly following induction of anaesthesia in all three groups; the magnitude of MAP decreases was greater after nicardipine 30 μg.kg^{-1} than in the other groups ($p < 0.01$). After intubation, MAP increased significantly in patients given saline or nicardipine 20 μg.kg^{-1} ($p < 0.01$ and $p < 0.05$ respectively). The increase in MAP was significantly greater after saline than after nicardipine 20 μg.kg^{-1} ($p < 0.01$). The increase above baseline values persisted until 2 and 1 min after intubation in the saline and nicardipine 20 μg.kg^{-1} groups respectively. In contrast, there was no significant increase in MAP

Table 2. Effects of nicardipine on mean arterial pressure (MAP), heart rate (HR) and rate-pressure product (RPP) in normotensive patients.

Dose (μg.kg^{-1})	Baseline	Before intubation	After intubation			
			immediate	1 min	2 min	3 min
MAP (mmHg)						
0	86 (9)	78 (12)*	117 (16)**	107 (11)**	100 (12)**	90 (10)
20	87 (8)	76 (13)*	98 (15)*‡	96 (13)*†	91 (9)	87 (8)
30	89 (11)	66 (8)**†	88 (8)‡	89 (7)‡	86 (9)‡	81 (6)*†
HR (beats.min^{-1}						
0	79 (10)	93 (13)*	101 (9)**	97 (9)**	95 (9)**	93 (11)**
20	77 (17)	93 (6)**	101 (8)**	98 (11)**	96 (10)**	93 (9)**
30	81 (12)	94 (12)**	110 (11)**	110 (13)**	106 (13)**	103 (16)**
RPP (mmHg. beat.min^{-1})						
0	9511 (2516)	9680 (1222)	15535 (2741)**	14338 (2344)**	12838 (2197)**	11694 (1943)*
20	9439 (2721)	9941 (1666)	13746 (2411)**	12825 (2325)**	12142 (2037)**	11294 (1697)*
30	10322 (2249)	9201 (1616)	13758 (2069)**	14224 (2297)**	13135 (2740)**	11742 (1992)**

*$p < 0.05$, **$p < 0.01$ compared with baseline values. †$p < 0.05$, ‡$p < 0.01$ compared with saline group. Data represent mean (SD).

Table 3. Effects of nicardipine on mean arterial pressure (MAP), heart rate (HR) and rate-pressure product (RPP) in hypertensive patients.

			After intubation			
Dose (μg.kg^{-1})	Baseline	Before intubation	immediate	1 min	2 min	3 min
MAP (mmHg)						
0	102 (10)	99 (14)	137 (17)**	138 (10)**	128 (6)**	124 (6)**
20	104 (17)	79 (9)**‡	104 (18)‡	105 (11)‡	101 (14)‡	98 (11)‡
30	101 (13)	72 (7)**‡	86 (13)*‡	92 (12)‡	91 (13)‡	87 (15)‡
HR (beat.min^{-1})						
0	80 (13)	94 (7)*	100 (13)**	101 (12)**	100 (12)**	96 (11)**
20	82 (16)	88 (15)	95 (15)	95 (16)	92 (16)	93 (14)
30	81 (15)	93 (13)*	95 (12)**	98 (11)**	96 (11)**	94 (12)*
RPP (mmHg. beat.min^{-1})						
0	11103 (2555)	12424 (1769)	19071 (3342)**	17771 (3421)**	17473 (2384)**	16671 (2122)**
20	12017 (3496)	9812 (1862)*‡	14199 (3303)‡	14026 (2453)‡	12979 (2570)‡	12926 (2573)‡
30	11362 (2861)	9684 (1911)‡	11244 (1898)‡	12495 (2279)‡	12120 (2331)‡	11671 (2413)‡

*p < 0.05, **p < 0.01 compared with baseline values. ‡p < 0.01 compared with saline group. Data represent mean (SD).

after intubation in patients who had received nicardipine 30 μg.kg^{-1}. HR increased significantly after induction of anaesthesia, and further increases were noted after intubation in all three groups ($p < 0.01$). There were no significant differences in maximal HR changes after intubation between patients who received saline and those given nicardipine 20 μg.kg^{-1}; patients given nicardipine 30 μg.kg^{-1} showed a greater increase. HR remained higher than baseline for 3 min after intubation in all three groups. RPP increased significantly after intubation in all groups ($p < 0.01$); there were no significant differences in RPP among the three groups during the study period.

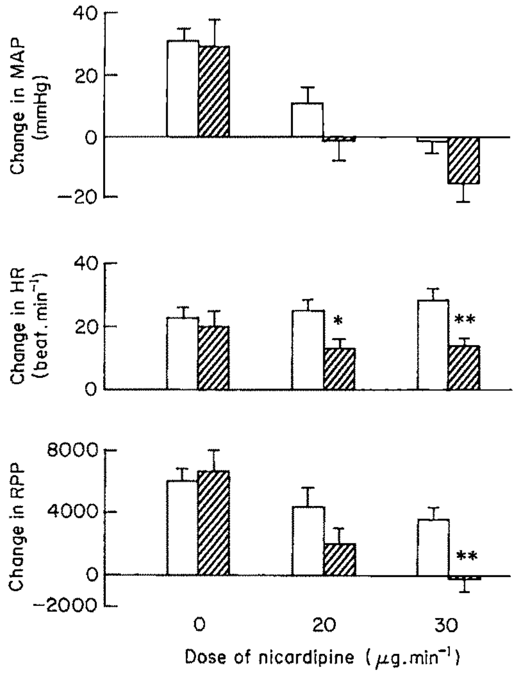

Figure 1. Comparison of changes in mean arterial pressure (MAP), heart rate (HR) and rate-pressure product (RPP) after laryngoscopy and tracheal intubation in normotensive (☐) and hypertensive (▨) patients who received saline, or nicardipine 20 or 30 μg.kg^{-1}. Data represent changes between baseline values and those immediately after tracheal intubation. *$p < 0.05$, **$p < 0.01$ compared with normotensive patients at the same dose of nicardipine. Bars represent SEM.

In the hypertensive patients (Table 3), baseline values of MAP, HR and RPP were comparable in patients who received saline or nicardipine 20 or 30 μg.kg^{-1}. MAP decreased significantly after induction of anaesthesia in both nicardipine groups ($p < 0.01$) but not in the saline group. After intubation, MAP increased significantly in the saline group ($p < 0.01$), but there was no increase in MAP after intubation in patients who had received either dose of nicardipine. HR increased significantly after induction and after intubation in hypertensive patients given saline or nicardipine 30 μg.kg^{-1}; the increase in HR in patients given nicardipine 20 μg.kg^{-1} was not significant. RPP increased significantly after intubation in the saline group ($p < 0.01$). In contrast, patients who had received nicardipine 20 or 30 μg.kg^{-1} did not exhibit significant increase in RPP after intubation.

Figure 1 shows the changes from baseline values in MAP, HR and RPP immediately after tracheal intubation in normotensive and hypertensive patients. The suppressive effect of nicardipine on the change in MAP was similar in normotensive and hypertensive patients. However, the increases in HR and RPP associated with tracheal intubation were suppressed by nicardipine significantly more in hypertensive patients than in normotensive patients.

One hypertensive patient in the saline treatment group had premature ventricular contractions related to intubation. This arrhythmia did not require treatment. No adverse reaction was observed in any other patient.

Discussion

Hypertensive patients have an exaggerated vasopressor response to many forms of stress, both in the conscious state and during anaesthesia. An increase in blood pressure associated with laryngoscopy and tracheal intubation is potentially dangerous, and may lead to left ventricular failure, myocardial ischaemia or cerebral haemorrhage [10, 20]. Therefore, it is important to be aware of the potential problem and to be particularly cautious with patients who are already hypertensive.

The present study has demonstrated that intravenous nicardipine prevents the increase in MAP associated with laryngoscopy and tracheal intubation in normotensive and hypertensive patients. Although HR increased in both groups, the degree of increase was less in hypertensive patients than in normotensive patients; consequently, nicardipine prevented the increase in RPP after intubation in hypertensive patients but not in normotensive patients. The reason for the differences may relate to different sensitivities of the baroreflex-mediated response because of peripheral vasodilatation induced by nicardipine, or, more probably, an effect of the pre-operative oral antihypertensive medication. RPP greater than 20 000 has been shown to correlate with angina and myocardial ischemia [21–23]. In this study, mean RPP after intubation was near 20 000 in hypertensive patients who received saline, but nicardipine prevented almost completely the increase in RPP in hypertensive patients.

Numerous pharmacological methods have been tried in an attempt to attenuate the circulatory responses to laryngoscopy and tracheal intubation [1–9]. However, none has achieved widespread acceptance because the reflex is not completely blocked or because the agents used are too long-acting or have undesirable side effects. The onset of action of nicardipine is rapid and its duration is fairly short; maximum effect is evident approximately 1 min after intravenous administration and the changes recover in 10–15 min in man [12,24]. Nicardipine protects against cardiac ischaemic effects by increasing coronary perfusion, oxygen delivery and aerobic metabolism [16–18]. Nicardipine has been administered intravenously during anaesthesia with isoflurane, fentanyl and halothane, with no untoward effects [25–27]. Cardiac function after nicardipine is adequately preserved even in the presence of beta-blockers [14]. Thus nicardipine appears to be an appropriate agent for attenuation of circulatory responses to laryngoscopy and tracheal intubation in patients with cardiovascular disease.

In conclusion, intravenous nicardipine prevented effectively the circulatory responses to laryngoscopy and tracheal intubation in hypertensive patients after induction of anaesthesia with thiamylal.

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CASE REPORT

Pulmonary embolism confirmed by transoesophageal echocardiography

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Summary

A 60-year-old patient suffered a pulmonary embolism following the application of an Esmarch and pneumatic tourniquet before arthroscopy of the knee. The diagnosis was suspected because of sudden hypotension, ECG changes, a decrease in end-expiratory carbon dioxide concentration and oxygen desaturation as indicated by pulse oximetry. Before performing a sternotomy and cardiopulmonary bypass for removal of pulmonary artery clots, the diagnosis was confirmed by the demonstration of severe right ventricular strain using transoesophageal echocardiography.

Key words

Complications; pulmonary embolism.
Measurement techniques; transoesophageal echocardiography.

The diagnosis of peroperative pulmonary embolism is usually made by patient history, the sudden onset of cardiocirculatory instability, changes in end-expiratory carbon dioxide tension and oxygen saturation. However, before deciding to perform an urgent cardiopulmonary bypass procedure for clot removal from the pulmonary artery, an additional, readily available, noninvasive method for confirmation of the diagnosis would be greatly welcomed, especially when survival is not threatened immediately, but may be compromised in the following hours. A case is presented where transoesophageal echocardiography was used to demonstrate right ventricular strain, and confirmed the suspected diagnosis.

Case history

Following a valgus trauma of the left knee, a 60-year-old male patient sustained a fracture of the tibial plateau and possible meniscal and ligamental injury. The leg was immobilised in plaster for 6 days, after which the patient was scheduled for diagnostic arthroscopy, and osteosynthesis of the fracture. The patient's history and pre-operative examination revealed no pre-existing pathology, except for a prolongation of the Q-T interval and nonspecific ST changes on the ECG. Two hours before operation the patient received lorazepam 2.5 mg sublingually, as premedication. After starting routine monitoring (pulse oximetry, ECG, automatic blood pressure measurement) and pre-oxygenation for 2 min, anaesthesia was induced with fentanyl, 2 μg.kg^{-1}, and propofol 2 mg.kg^{-1}. Two minutes after the administration of vecuronium 0.1 mg.kg^{-1}, the patient's trachea was intubated and the lungs mechanically ventilated, to maintain an end-expiratory carbon dioxide tension of 4.3–4.7 kPa.

Anaesthesia was maintained with isoflurane 0.5–1.2%, end-expiratory concentration, and nitrous oxide 60% in oxygen. Intravenous cefuroxime 2 g was administered for infection prophylaxis. During induction and preparation of the patient, saturation and end-expiratory carbon dioxide concentration remained stable. Twenty minutes after induction of anaesthesia the leg was exsanguinated by application of an Esmarch bandage and inflation of a pneumatic tourniquet around the thigh. The end-expiratory carbon dioxide tension suddenly decreased from 4.3–3.3 kPa. The minute ventilation was decreased from 7.8 to 7.2 l.min^{-1}. Five minutes later, end-expiratory carbon dioxide tension had further decreased to 3.0 kPa, while oxygen saturation decreased from 96 to 92%. The inspired oxygen concentration was increased to 100%, and the breathing circuit and tracheal tube were checked for correct function and position.

Auscultation of the chest was normal. Systolic blood pressure decreased to 80 mmHg, and the end-expiratory carbon dioxide tension decreased further to 2.5 kPa and the

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saturation to 65%. There were no abnormalities of the cardiac rhythm but ECG monitoring revealed moderate ST depression. A pulmonary embolism was suspected, and the minute ventilation was increased to 10 l and a radial artery and central venous (right internal jugular vein) catheter were inserted. The right atrial pressure was 12 mmHg. The pH of the arterial blood was 7.34, and arterial $P\text{CO}_2$ and $P\text{O}_2$ were 5.7 and 6.3 kPa, respectively. Hypotension was successfully treated with repeated intravenous doses of ephedrine (15 mg in total) and a dopamine infusion at $6\,\mu\text{g.kg}^{-1}.\text{min}^{-1}$. The heart rate increased from 86 to 130 beat.min^{-1}. Oxygen saturation improved to 80%, while the end-expiratory CO_2 concentration remained low. A 12-lead ECG revealed a QRS axis of +30°, ST segment depression in the anterolateral precordial recordings, and T inversion in lead III. Chest X ray indicated possible enlargement of the heart. To confirm the diagnosis of pulmonary embolism, transoesophageal echocardiography was performed, showing a severely hypokinetic, dilated right ventricle. An urgent sternotomy was performed, and cardiopulmonary bypass started. Two hours after the onset of the symptoms a substantial amount of thrombus was removed from both pulmonary arteries. The postoperative period was complicated by temporary right ventricular dysfunction which required 12 days of treatment in the intensive care unit.

Discussion

Pulmonary embolism is a serious and potentially fatal complication. It is common after major abdominal, pelvic, and orthopaedic surgery. Risk factors include immobilisation, smoking, neoplasia, oral contraceptives, pregnancy, and atrial fibrillation. In this case, application of an Esmarck tourniquet to an immobilised leg provoked mobilisation of blood clots.

The symptoms of pulmonary embolism are often nonspecific: thoracic pain, cardiac arrhythmias, hypotension, dyspnoea, increased right atrial pressure, and ECG signs of right ventricular strain [1, 2]. Radiographic signs are usually absent [3]. During general anaesthesia subjective signs are absent, but the diagnosis is helped by the use of capnography [4] and pulse oximetry [5]. The decrease in end-expiratory carbon dioxide tension is proportional to the increase in deadspace ventilation, and thus to the extent of the pulmonary embolism [6, 7]. Although the diagnosis of pulmonary embolism is strongly suggested by the sequence of events, the sudden circulatory changes, and by capnography and pulse oximetry data, alternative diagnoses have to be considered. Severe myocardial ischaemia, involving large portions of the right and left ventricle resulting in acute heart failure, has to be excluded before proceeding with the surgical treatment of pulmonary embolism. Extensive myocardial ischaemia can produce a decrease in cardiac output, resulting in hypotension, desaturation, and decreased CO_2 removal by the lungs. In this case, the demonstration, by means of transoesophageal echocardiography, was of an hypokinetic, dilated right ventricle, and a normally contracting, but hypovolaemic left ventricle. This added evidence for the diagnosis of pulmonary embolism [8] prompts the decision to perform urgent cardiopulmonary bypass. In conclusion, transoesophageal echocardiography may be a useful tool for the confirmation of the diagnosis of pulmonary embolus.

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CASE REPORT

Internal jugular catheterisation

Blood reflux is not a reliable sign in patients with thoracic trauma

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Summary

An internal jugular catheter, which was inserted into a patient with a traumatic haemopneumothorax, accidentally entered the pleural cavity. This was initially undetected because the two signs most frequently used to confirm correct placement, those of blood reflux and fluctuation of central venous pressure with respiration, were positive. A number of precautions are suggested which should be taken when central venous catheters are inserted in patients with thoracic trauma.

Key words

Veins, jugular; cannulation, complications.
Complications; haemopneumothorax.

There are a number of ways in which the correct position of catheters in central veins can be verified, but the two which are most frequently used are those of reflux of blood back up the catheter and fluctuation of the central venous pressure (CVP) with respiration. In cases of thoracic trauma, a basic rule is to attempt venous puncture on the same side as the damaged lung first of all, so that in the event of a mishap such as puncture of an emphysematous bulla, the function of the healthy lung is preserved.

In this report we describe a complication of internal jugular vein cannulation in a patient with an ipsilateral haemothorax. Since reflux of blood and respiratory fluctuations led us to believe that the cannula was correctly sited, we suggest further precautions which should be taken during central venous cannulation in patients with thoracic trauma, even when the high anterior approach to the internal jugular vein is used.

Case history

A 30-year-old, 75-kg Caucasian man with a traumatic haemoperitoneum and a right haemopneumothorax was admitted for emergency laparotomy. A chest drain was inserted and 450 ml of blood drained into the bottle over 30 min, after which the drainage stopped. The patient was fully conscious and his blood pressure and pulse rate just before induction were 120/80 mmHg and 130 beat.min^{-1} respectively. Anaesthesia was induced with fentanyl 0.1 mg, thiopentone 375 mg and vecuronium 8 mg and the trachea was intubated. Maintenance was with nitrous oxide in oxygen and the lungs were mechanically ventilated. At laparotomy, extensive lacerations of the right lobe of the liver and the right kidney were found. The right internal jugular vein was punctured at the first attempt via a high anterior approach and a 16-G catheter was inserted using a Seldinger technique (Vygon Leadercath 14-G; code 124.20). The procedure was uneventful and there was reflux of blood and fluctuation of central venous pressure with respiration. The lacerations in the liver and kidney were repaired and two units of packed red cells were transfused through the catheter. Although the patient was haemodynamically stable, the CVP measurement was zero. Soon after transfusion with the first unit of blood, drainage from the chest suddenly increased. The blood transfusion was followed by Ringer lactate and saline, after which the blood from the chest drain appeared to be more dilute. However, blood could still be aspirated back up the catheter and respiratory fluctuation of the CVP was still present. Over a period of about 30 min, 1500 ml had drained into the bottle, therefore the decision was made to perform a thoracotomy. After the patient was turned into the left lateral position, the CVP was found to have increased to 10 cmH_2O. At thoracotomy, the catheter was seen to have perforated the wall of the superior vena cava and was lying in the pleural cavity, pointing upwards and to the right, with the tip well above the right atrium. The catheter was withdrawn, two pulmonary lacerations were sutured and the chest closed with a thoracic drain in place. No more bleeding occurred and the patient was discharged from the intensive care unit a few days later.

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Discussion

A central venous catheter is useful for assessing fluid replacement and administering large volumes of fluid rapidly. The internal jugular vein is considered to be the safest route for catheterisation [1]. However, many complications have been reported, even with this route [2]. Although some textbooks mention that blood reflux and respiratory fluctuations are not reliable signs of correct placement [3], we have been unable to find any case reports in which these signs were present when the catheter was not in a central vein.

The position of the catheter within the pleural space explains all the signs observed: the flow of blood into the infusion set, the movement of the fluid column synchronously with respiration and the apparent sudden increase in central venous pressure when the patient was turned on his side (Fig. 1). The use of the Seldinger technique is considered to be the safest method of vascular cannulation [4], although the equipment is more expensive. In this case, since the high approach to the internal jugular vein was used, it is probable that the guide wire itself was responsible for the false passage; a possible explanation is that it had been inserted the wrong way round, with the rigid end rather than the flexible end first.

We conclude, therefore, that in patients with chest trauma, if a central venous catheter is inserted on the same side as a haemothorax, or if blood has already been transfused through the catheter, reflux of blood and fluctuation of venous pressure with respiration may not always be reliable signs with which to confirm central venous catheterisation.

Thus, there are a number of basic rules which should be observed in a patient with a haemothorax, in order to minimise the risks of accidental placement of the catheter within the pleural cavity. Before the guide wire is introduced, care should be taken to identify and insert the end with the flexible tip. The first blood aspirated from the catheter should be put in a test tube and observed for clot formation. If clots do not form in 15–30 min, it suggests that the catheter is sited in the pleural space. The chest drainage should be observed, in particular to look for a correlation between changes in the rate of drainage and the rate at which the fluid is infused through the catheter. Likewise, the composition of both should be compared for similarities in dilution or colour, particularly if substances such as fat emulsions, methylene blue or multivitamin preparations are being transfused. The catheter should not be used for blood transfusion, if that is possible, to avoid confusion and wastage of blood. Finally, the medical and nursing staff should be aware of this complication, and of the clinical signs which should lead to its diagnosis.

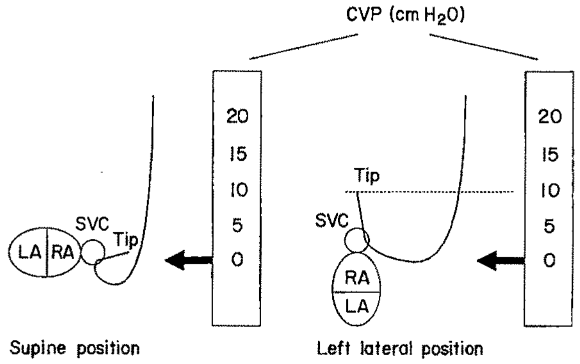

Fig. 1. Transverse section at heart level. Supine position: Left and right atria (LA and RA), superior vena cava (SVC) and the tip of the catheter (Tip), out of the vessel and pointing to the right side, are all at the same level (central venous pressure zero cmH_2O). Left lateral position: the tip of the catheter became much higher than the RA, and produced central venous pressure readings of about 10 cmH_2O.

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Anaesthesia, 1992, Volume 47, pages 32–33

CASE REPORT

Inorganic fluoride in prolonged isoflurane sedation

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Summary

An 18-year-old girl received isoflurane sedation for 48 h to facilitate mechanical ventilation. This resulted in a serum inorganic fluoride level of 37.3 μmol.l⁻¹ when the isoflurane was stopped. As the serum fluoride level may continue to rise after isoflurane and as this level is approaching toxicity, the role of isoflurane sedation in the critically ill should be approached cautiously.

Key words

Anaesthetics, volatile; isoflurane.
Ions; fluoride.

Many patients in intensive care units require sedation and a variety of drugs are used to provide this. Isoflurane has many desirable characteristics including a rapid onset and offset of action and minimal metabolism. Isoflurane was used for 48 h to provide sedation in an 18-year-old girl undergoing mechanical ventilation of the lungs in the intensive care unit.

Case history

A previously healthy 18-year-old girl was admitted to hospital because of status epilepticus. Earlier on the day of admission she had been found having generalised grand mal convulsions at home. It was believed she had been fitting for a number of hours, as observers had noticed unusual noises coming from her bedroom approximately 5 h before.

On examination in the Emergency Department she had recurrent generalised seizures and was centrally cyanosed. Arterial blood gases revealed a pH of 7.23, $P\text{aco}_2$ 6.25 kPa, $P\text{ao}_2$ 8.5 kPa, bicarbonate 20 mmol.l^{-1} and a base deficit of 8 mmol.l^{-1}. Her blood pressure was 130/90 mmHg, her pulse rate of 120 min^{-1} was regular and her temperature was 37.5°C. A chest X ray taken at the time of admission showed collapse and consolidation of the left lower lobe.

Intravenous midazolam 5 mg was given to control the seizures. This had to be repeated on a number of occasions for recurrent seizures. The patient was paralysed and the trachea intubated to permit artificial ventilation of the lungs. This controlled the seizures and ensured adequate oxygenation.

Further investigations, a toxicology screen, blood alcohol level, lumbar puncture, serum electrolytes and liver function tests were normal. A full blood count showed white cells of 32.8×10^9.l^{-1} and a haemoglobin of 154 g.l^{-1}. A cranial computerised tomogram scan showed the presence of some calcification involving parts of both the lentiform nuclei and the heads of the caudate nuclei but was otherwise normal.

The patient was subsequently managed in the intensive care unit, her seizures were controlled gradually with midazolam and phenytoin. She remained hyperflexic, restless and had occasional extensor spasms of all four limbs. Left lower lobe pneumonia progressed to involve all the left lung and subsequently the right lung. Oxygen requirements increased because of the progressing pneumonia, and her lungs became less compliant. She required 60–90% inspired oxygen concentration to prevent hypoxaemia. Despite a continuous infusion of midazolam with intermittent narcotic injections, a depth of sedation to permit safe ventilation was difficult to achieve. Isoflurane was therefore commenced, in an initial concentration of 2%, for approximately 2 min and subsequently in a concentration of 0.75%. The isoflurane was vaporized using a Tec 3 continuous flow vaporizer (Ohmeda, Steeton, West Yorkshire) and administered with oxygen-enriched air via the low pressure inlet of a Servo 900 C ventilator (Siemens). This provided excellent sedation and permitted a reduction in $F\text{io}_2$ from 0.8 to 0.6. However, the lung compliance remained unchanged. After 48 h, no further improvement in the patient's condition was apparent and because of the rapid use of isoflurane (approximately a 100 ml bottle every

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2 h) it was stopped. Subsequent sedation was achieved with midazolam and papaveretum.

Respiratory failure progressed and the patient died 17 days after admission to the intensive care unit from hypoxia and multiple pneumothoraces secondary to pulmonary barotrauma.

Blood was collected 24 h and 48 h after commencing the isoflurane for measurement of serum inorganic fluoride levels. Serum fluoride levels were measured using an ion-specific electrode (Orion Research Inc Boston Mass) and were shown to be 18 μmol.l^{-1} and 37.3 μmol.l^{-1} at 24 and 48 h respectively.

Discussion

Previously isoflurane has been used to control status epilepticus, to treat bronchial asthma and to sedate patients in the intensive care unit [1–3]. The various reports and our experience indicate that it is a useful agent to use in the intensive care unit and allows smooth sedation in patients where this was difficult with other methods of sedation.

Although less than 0.2% of isoflurane can be recovered as urinary metabolites [4], there are reports of significant increases in inorganic fluoride levels following its use [5, 6]. Kong *et al.* showed that plasma fluoride levels continued to rise after cessation of isoflurane sedation and were still elevated in some patients after 48 h [7]. This is in keeping with previous reports which demonstrate a rise in fluoride levels several hours after stopping anaesthesia with isoflurane [8, 9]. It was recently reported that the plasma fluoride concentration reaches its peak some 16 h after the end of isoflurane administration [10].

We estimate that our patient received approximately 30 MAC h of isoflurane, which is modest when compared with some other reports of 6 days [5], 73 MAC h [11] and 107 MAC h [6]. These reports were associated with plasma fluoride levels of 18 μmol.l^{-1}, 9.5 μmol.l^{-1} and 36.8 μmol.l^{-1} respectively. However, the plasma fluoride level in our patient was greater than that seen in these reports. A fluoride level of 50 μmol.l^{-1} is regarded as the toxic level [8]. A level of 37.3 μmol.l^{-1} at the time of stopping isoflurane could easily rise to this level accepting that previous reports have demonstrated that the plasma fluoride level continues to rise after stopping isoflurane [8–10]. The fluoride level after 48 h was more than twice the level at 24 h. If this rate of rise in fluoride was continued, potentially toxic levels would soon be reached. A recent report demonstrated inorganic fluoride levels up to 81.6 μmol.l^{-1} in some patients, without causing apparent renal disfunction, despite using smaller concentrations of isoflurane than that used in our patient [10].

Critically ill patients do not always obey normal physiological rules and pharmacokinetics may be altered. This is especially true for midazolam [12, 13] and caution must be exercised when extrapolating data from physiologically normal patients to critically ill patients. The fact that such a high level of plasma fluoride was seen after 48 h use in our patient, who was critically ill, is a cause for some concern.

Isoflurane provides an excellent flexible means of managing patients in intensive care units who require sedation for ventilation. However, its use must be safe. This can only be shown by controlled trials in critically ill patients. Until this has clearly been demonstrated the widespread use of isoflurane for long-term sedation in critically ill patients must not be regarded as routine practice.

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Anaesthesia, 1992, Volume 47, pages 34–37

CASE REPORT

Failure of continuous three-channel Holter monitoring to detect acute peri-operative myocardial infarction

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Summary

Continuous peri-operative three-channel Holter monitoring in a 70-year-old patient undergoing elective hip arthroplasty failed to show onset and progression of a lethal postoperative myocardial infarction, which was clearly visible in a 12-lead electrocardiogram. The modified bipolar leads used for Holter monitoring differed from the corresponding leads of the 12-lead electrocardiogram. The limitations of Holter monitoring applied to clinical management and research are highlighted.

Key words

Complications; myocardial infarction.
Equipment; Holter monitor.

Myocardial ischaemia in the peri-operative period is predominantly silent and may not be detected by clinical assessment [1], but the use of Holter monitoring has increased our knowledge of this event [2–4]. Since the sensitivity of ischaemia detection in the electrocardiograph depends on the number and selection of leads [5–7], the sensitivity of Holter monitoring, which uses two or three modified leads, is inferior to the sensitivity of a conventional 12-lead electrocardiogram (ECG). We present a case where continuous three-channel Holter monitoring missed the onset and progression of a fatal, acute myocardial infarction which was clearly detectable in the 12-lead ECG.

Case history

A 70-year-old patient was scheduled for elective total hip arthroplasty. He had no history of heart disease, chest pain, diabetes or smoking, but had, for the past 20 years, experienced arterial hypertension that was treated with nifedipine and amiloride.

Physical examination showed a blood pressure of 135/80 mmHg and a heart rate of 76 beat.min^{-1}. The pre-operative 12-lead electrocardiogram (ECG) was identical with an ECG recorded 5 years previously, and both revealed significant Q waves in III and aVF and negative T waves in all inferior leads (II, III, aVF), suggestive of a previous inferior myocardial infarction (Fig. 1).

Total hip arthroplasty was performed under spinal anaesthesia. The intra-operative course and recovery period were uneventful. On the evening of the first postoperative day, mild hypotension (100/60 mmHg) and tachycardia (110 beat.min^{-1}) occurred, and persisted despite infusion of blood and plasma expanders. On the morning of the second postoperative day, sweating, nausea and vomiting occurred. The patient denied having chest pain. Physical examination revealed hypotension (90/70 mmHg), tachycardia (110 beat.min^{-1}) and pulmonary oedema. A 12-lead ECG showed a new elevation of the ST segment in III and aVF and a depression of the ST segment in I and aVL (Fig. 2); a quantitative analysis of serum creatine kinase (CK) (CK 2850 IU, CK-MB 12%) revealed a diagnosis of acute inferior myocardial infarction. The patient was transferred to the coronary care unit. Echocardiography showed akinesia of the inferior, posterior, and right ventricular free wall. The patient died of intractable low cardiac output syndrome on the 14th postoperative day. Permission for an autopsy was not given.

Methods

The patient had been enrolled in an ongoing clinical study of peri-operative ischaemia. He was monitored with a three-channel Holter ECG recorder (Marquette

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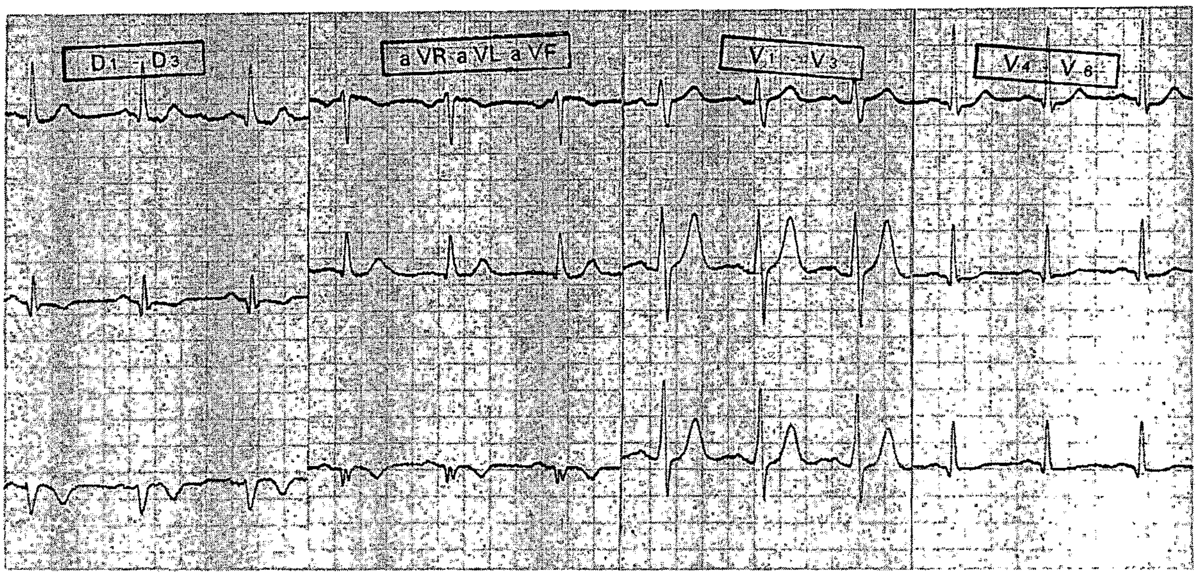

Fig. 1. Pre-operative 12-lead ECG, which corresponds to column (a) in Figure 3.

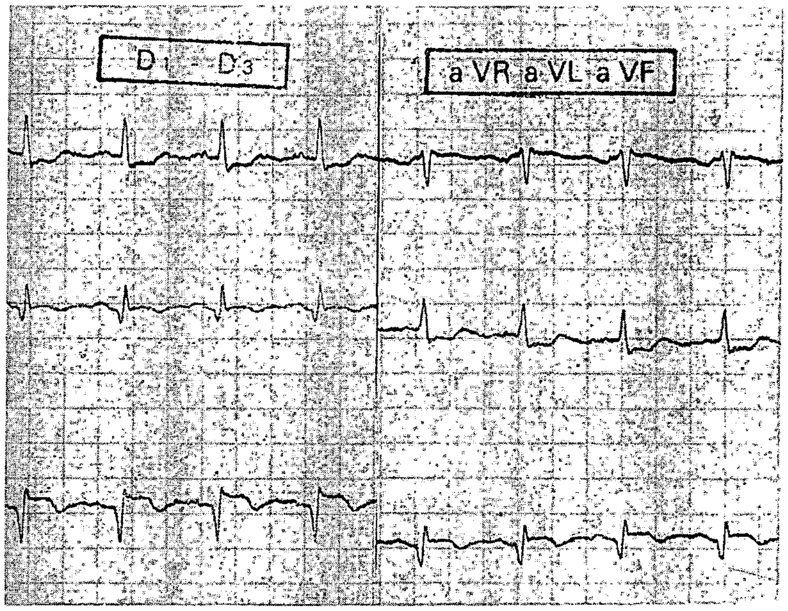

Fig. 2. A 12-lead ECG performed on the second postoperative day shows the new ST segment elevation in III and aVF, and a depression in the ST segment in I and aVL; this corresponds to column (d) in Figure 3.

Electronics, series 8500) from the afternoon before surgery until transfer to the coronary care unit after the diagnosis of an acute myocardial infarction (total recording time 69 h). Following study protocol, three modified bipolar leads were used and placed according to the users' manual (Marquette): V_5 (positive electrode on the fifth intercostal space at the left anterior axillary line, negative electrode below right clavicle just lateral to the sternum); V_3 (positive electrode on the fourth intercostal space at the left sternal edge, negative electrode on the manubrium); and aVF (positive electrode placed on the sixth rib at the left mid-clavicular line, negative electrode just below the left clavicle at the midclavicular line). The ground electrode was placed on the lower right chest wall.

Holter tapes were analysed on a computerised ECG analysis system (Marquette Laser SXP). Recording quality was excellent, allowing reliable interpretation at all times during the observation period. Compared with the pre-operative 12-lead ECG, T wave depression in Holter leads V_5 and V_3 differed from the former, while aVF (Holter) was similar to II (12-lead ECG) (Fig. 3, Column 'a'). Neither elevation nor depression of the ST segment was observed in any lead at any time. Before and during operation, a marked T wave depression was present in all three Holter leads. Negativity of the T wave varied with heart frequency and became less pronounced after onset of tachycardia on the evening of the first postoperative day (Fig. 3). The amplitude of the QRS complex varied with heart frequency and decreased after the onset of tachycardia.

Discussion

Our patient died of a peri-operative myocardial infarction, which was diagnosed just after the onset of a severe low

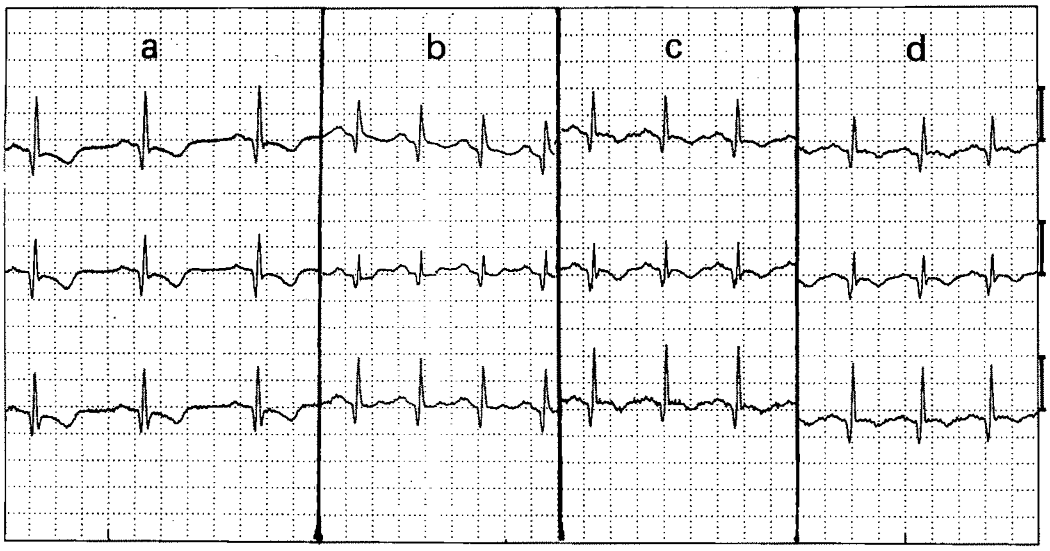

Fig. 3. The ECG performed by continuous Holter monitoring using three bipolar leads (V_5 upper line, V_3 middle line, aVF base line). (a) pre-operative day. (b) onset of tachycardia in the evening of the first postoperative day. (c) occurrence of nausea and vomiting on the morning of the second postoperative day. (d) last recording after diagnosis of myocardial infarction.

cardiac output syndrome. This case emphasises that peri-operative myocardial ischaemia is predominantly silent [1–4] and, therefore, is underestimated by clinical assessment alone. The use of Holter monitoring improved the identification of peri-operative ischaemia [2–4] and to our knowledge this is the first time Holter monitoring has failed to record a major ischaemic event. Although minor electrocardiographic changes occurred in the Holter tracing, these were insufficient to allow a diagnosis of a myocardial infarction clearly detectable in a conventional 12-lead ECG.

The sensitivity of ischaemia detection using Holter monitoring in the peri-operative period has not yet been determined. Generally, the sensitivity of electrographic ischaemia detection depends on the number and selection of leads [5–7]. In Holter monitoring, a minimum of three leads was reported to be necessary for comprehensive quantitation of the total ischaemic burden [8]. Since the number of leads in Holter monitoring is limited due to technical (capacity of devices available) and practical (patient's comfort) reasons, the optimal selection of leads might improve sensitivity. During exercise treadmill testing, the most sensitive leads are V_5, V_6 and II, while during the intra-operative period, the most sensitive leads are V_5 and V_4 [5,7]. Whether the latter data provided with a 12-lead ECG can be applied to Holter monitoring using modified bipolar leads remains unresolved.

Our patients's pre-operative ECG was suggestive of a previous inferior myocardial infarction. Accordingly, the study protocol called for Holter monitoring to be performed using the leads V_5, V_3, and aVF. Had we been free to choose our lead placement, we probably would not have chosen an inferior lead, on the assumption that it was unlikely we would detect ischaemic events in the region of a suspected previous infarction. Although peri-operative myocardial reinfarction is a well known risk in patients with previous infarction [1], there are no data available concerning the localisation of reinfarction. The optimal selection of leads for peri-operative ECG monitoring of patients with a pathological 12-lead ECG remains an open question.

Real-time ECG monitoring with ST segment trending allows rapid therapeutic intervention and is widely used for bedside monitoring in intensive care units. Real-time Holter monitoring, using programmable devices with an acoustic alarm was introduced recently in clinical practice and was reported to be useful during the postoperative period [9–10]. However, our patient would not have benefited from this monitoring because of the position of the electrodes.

Several recently published studies discuss the peri-operative occurrence of silent ischaemic events [2–4]. However, our case emphasises that the frequency of silent ischaemia might have been underestimated.

This case illustrates the limitations inherent in Holter monitoring, which is of concern in both research and clinical management. An increase in the number of leads available and/or the determination of optimal lead selection will further improve the sensitivity of Holter monitoring.

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CASE REPORT

Oesophageal achalasia causing respiratory obstruction

J. L. WESTBROOK

Summary

A patient with complete respiratory obstruction due to massive oesophageal dilatation is described. Immediate relief of symptoms and disappearance of the oesophageal swelling occurred after administration of sublingual glyceryl trinitrate. Nitrates cause a reduction in the lower oesophageal sphincter pressure in patients with oesophageal achalasia and in this case it is presumed that spasm of the lower oesophageal sphincter had been a major factor preventing decompression of the dilated oesophagus.

Keywords

Airway; obstruction.
Gastrointestinal tract; oesophagus, achalasia.
Pharmacology; glyceryl trinitrate.

Acute airway obstruction due to massive oesophageal dilatation is a rare complication of achalasia of the oesophagus. It is well described in the literature, but relatively few reports have been published in anaesthetic journals [1]. Emergency treatment previously described has included tracheostomy under local anaesthesia [2], passage of a nasogastric tube [3], tracheal intubation [4], transcutaneous needle puncture [5] and rigid oesophagoscopy [6]. A patient with achalasia of the oesophagus is described, whose acute airway obstruction was relieved by simpler measures.

Case history

A 90-year-old woman was referred to hospital by her general practitioner with a provisional diagnosis of congestive cardiac failure, which was based on a history of increasing shortness of breath of recent onset.

She was very dyspnoeic on arrival and the ambulance crew reported that she had become cyanosed during the journey, but that this was relieved by oxygen given through a Hudson mask. The patient was unable to give any history because she was too breathless to speak and on examination she was cyanosed despite supplementary oxygen. Her pulse rate was 90 beat.min^{-1} and regular, blood pressure 130/85 mmHg, the jugular venous pulse was not visible and the heart sounds were normal. There was slight pitting oedema of the ankles. Her chest expansion was poor but both sides moved equally, and the percussion note was resonant. On auscultation the breath sounds were reduced but vesicular, with no crackles or wheezes. In her neck there was a soft midline swelling about 7 cm in diameter which expanded on inspiration. It bulged over the suprasternal notch, was nonpulsatile and could be transilluminated.

Her cyanosis resolved with an increased oxygen flow via the facemask and therefore an urgent chest X ray and soft tissue X rays of the neck were arranged (Figs 1 and 2). The swelling was shown to be a massively dilated oesophagus which was compressing the trachea against the posterior aspect of the manubrium.

The patient's condition then deteriorated, she became cyanosed again and showed signs of upper airway obstruction. The dilatation of the oesophagus was thought to be due to acute lower oesophageal sphincter spasm and so the patient was given glyceryl trinitrate (GTN) 500 μg sublingually. Within 2 min the cervical swelling collapsed and the patient's dyspnoea was immediately relieved.

After the patient had recovered it was possible to take a more complete history. She had been investigated for symptoms of gastric reflux some months previously and barium studies performed at that time had shown a dilated oesophagus with reduced peristaltic movements. She gained symptomatic relief from an H_2 receptor antagonist and the condition was not investigated any further.

The chest X ray taken soon after the administration of the GTN shows a marked reduction in the size of the

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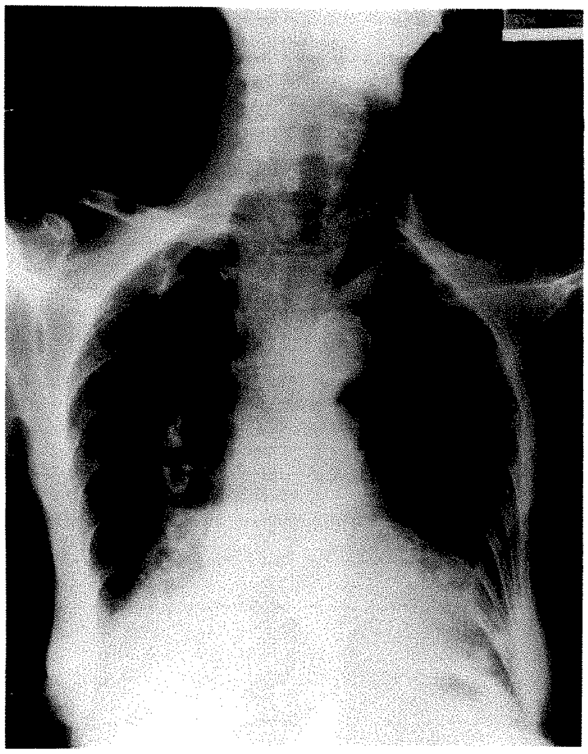

Fig. 1. PA chest X ray showing a massively dilated oesophagus extending up into the neck.

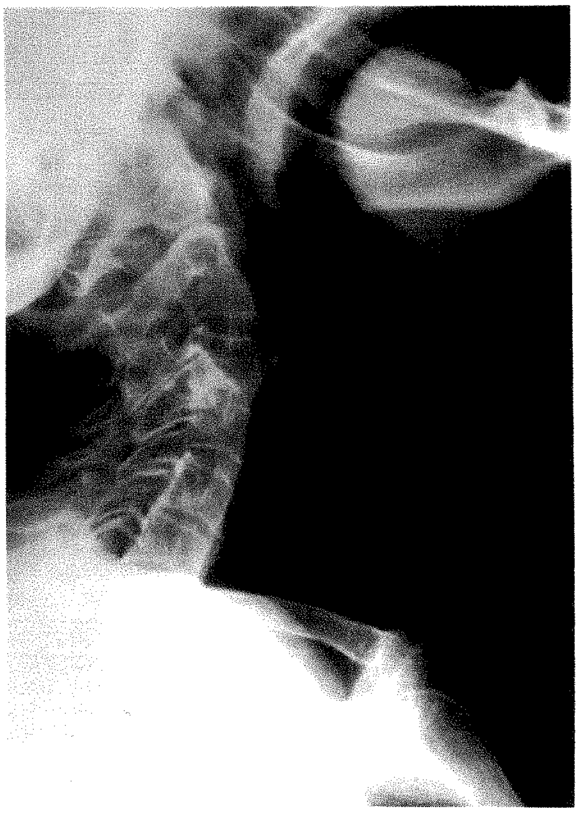

Fig. 2. Lateral soft tissue X ray of the neck. This shows increased anterior/posterior diameter of the oesophagus with a fold of oesophagus, at the level of the third cervical vertebra, preventing air from escaping to atmosphere. The trachea is seen compressed against the posterior aspect of the manubrium.

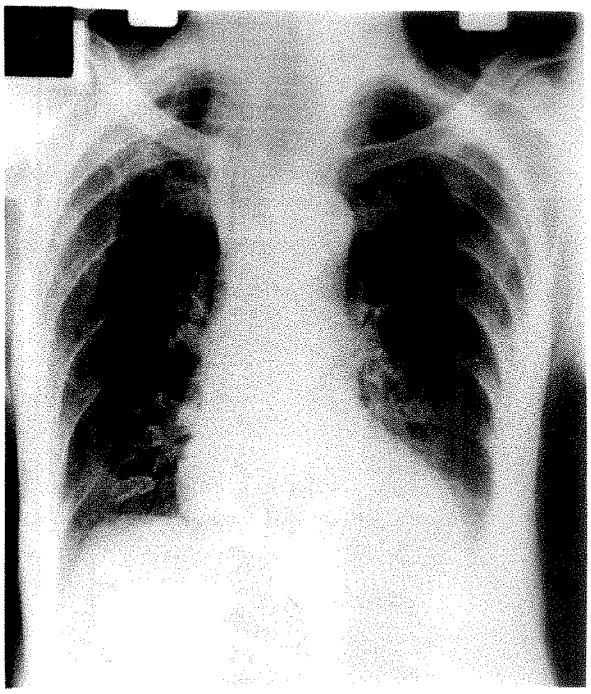

Fig. 3. PA chest X ray showing the reduced size of the oesophagus following treatment.

oesophagus (Fig. 3). The patient declined any further investigation or intervention and she was subsequently discharged with a supply of glyceryl trinitrate.

Discussion

We believe that this patient could not relieve pressure within her oesophagus because the tortuous folds acted as valves, preventing air that had entered the oesophagus from leaving it again. The oesophagus could not decompress into the stomach because the lower oesophageal sphincter was in spasm. The massively dilated oesophagus caused direct compression of the trachea against the manubrium sterni, resulting in acute respiratory distress due to airway obstruction.

In the absence of follow-up oesophagoscopy, oesophageal manometry or barium studies it is not possible to be certain about the underlying pathology. Malignancy is unlikely because of the long history and the patient is now known to have survived these events by 2 years. The two conditions that could cause this degree of oesophageal dilatation are achalasia of the oesophagus and a benign oesophageal stricture secondary to reflux oesophagitis. In view of the sequence of events, a lower oesophageal stricture is unlikely, since a significant scarring would be necessary to produce massive dilatation of the oesophagus and this would not be relieved by smooth muscle relaxants. However, spasm is a well recognised component of achalasia and its relief by the nitrates and calcium antagonists is well documented [7].

Gelfond *et al.* [7] demonstrated that nitrates afford prompt reduction in lower oesophageal sphincter pressure and confirmed the consequent emptying of the oesophagus with radionucleide studies. Nitrates have a role in the management of achalasia [8] but oesophageal dilatation and surgical myotomy remain the standard treatment, because of the side effects of chronic nitrate therapy. Gelfond *et al.* [9] studied the response of 24 patients with achalasia to isosorbide dinitrate and found that a mean lower oesophageal sphincter (LOS) pressure of 46.3 mmHg decreased to a mean of 15.3 mmHg after the nitrate.

In this case it appears that the reduction in lower oesophageal sphincter tone by glyceryl trinitrate was enough to allow decompression of the critically dilated oesophagus. This produced dramatic relief of symptoms and avoided the use of more invasive procedures.

Acknowledgment

I thank Dr M.D. Hellier FRCP for his kind permission to report this case.

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APPARATUS

An evaluation of the Brüel and Kjær monitor 1304

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Summary

A laboratory evaluation was performed on the Brüel and Kjær multigas monitor 1304, incorporating a pulse oximeter. The instrument was tested for accuracy, stability, response and delay times, frequency response and the effects of water vapour, alcohol, cyclopropane and sevoflurane. The instrument's performance was found to be within or very close to the manufacturer's specifications for accuracy, stability and response and delay times. It was unaffected by water vapour and alcohol and the effect of cyclopropane on the vapour channel was lower than has been reported for other analysers. The response to sevoflurane was of the same order as that of the other vapours. A 90% response to square wave changes of gas composition was maintained up to 60 breaths.min^{-1} *for* CO_2, O_2, *and* N_2O *and up to 40 breaths.min*$^{-1}$ *for the vapours when the nafion sampling tube was used.*

Key words

Equipment; multigas monitor.

The Brüel & Kjær Anaesthetic gas monitor Type 1304 is a multigas anaesthetic monitor with a built-in pulse oximeter. It simultaneously measures inspired and end-tidal concentrations of oxygen, carbon dioxide, nitrous oxide and either halothane, enflurane or isoflurane. Oxygen saturation is measured with a finger probe and the pulse plethysmogram can be displayed continuously. The sample flow rate is 90 ml.min^{-1} and can be returned to the patient system, after measurement, via a bacterial filter. The sample tubing used in the 1304 is made from a special type of plastic called nafion which permits the diffusion of water vapour and minimises adsorption of anaesthetic agents on the tubing.

Description of the instrument

The 1304 is mains powered, and can be used with 100–127 volts or 200–240 volts at 50–400 Hz. A back-up battery protects the data stored in the trend memory and provides power for the internal clock. Inspired and expired gas and vapour concentrations, respiratory rate, pulse rate and oxygen saturation are displayed numerically at all times. There is a graphic display of CO_2 concentration against time on one channel, while O_2, N_2O, vapour concentration or the pulse plethysmograph are shown on the second channel. The latter can be displayed with either manual or autoscaling gain. All the measurements can also be displayed as trends.

The 1304 is equipped with high/low alarm systems for all the relevant measurements but there is no audible signal associated with the pulse oximeter. The audio alarm can be silenced for 3 min, but should a new alarm situation arise, it is automatically reactivated. In addition there is a visual alarm for apnoea and pulse search. The date and time are displayed in the bottom left hand corner of the screen and the patient's identity can also be displayed via a keyboard facility in the set up menu.

External connections at the rear of the instrument allow interfacing with a personal computer system (RS 232C, serial trend), and connection to a video tape recorder or video plotter (CCIR standard or EIA standard). Figure 1 shows the instrument's display panel.

Principles used in measurement

CO_2, N_2O and anaesthetic vapours

The measurements are based on photoacoustic spectroscopy (PAS). When energy is applied to a gas, the gas will expand, thus causing an increase in pressure. If the applied energy is delivered in pulses, the pressure increase will be intermittent, resulting in a fluctuating pressure. If the

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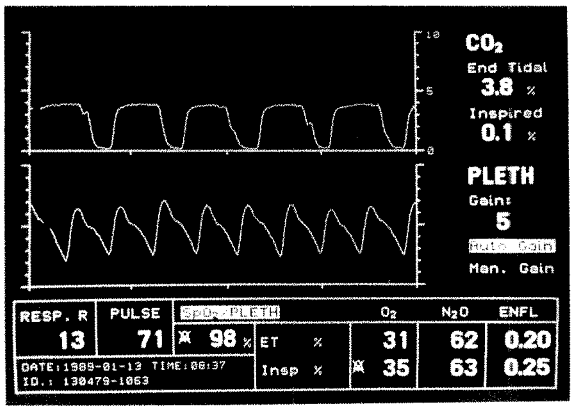

Fig. 1. The display panel of the Bruel and Kjær Monitor 1304.

frequency of pulsation is in the audible range, then the changes in pressure will create a sound wave which can be detected by a sensitive microphone. The amplitude of a signal caused by the pressure fluctuation is directly proportional to the concentration of gas present. CO_2, N_2O, and the anaesthetic vapours absorb infrared radiation to a varying extent, the absorption spectrum being specific for each gas. Broad band infrared radiation is chosen as the source of energy used to produce the increase in pressure, but in order to be able to differentiate between the signals for each measured gas, it is necessary to divide the emitted infrared beam into three different sections. For this purpose a chopper disk consisting of three concentric bands of holes is employed. This causes the emitted radiation to be modulated at three different frequencies.

The divided light beam then passes through three different optical filters which form one wall of the measuring cell (Fig. 2). Each of these filters allows only infrared radiation of a specific wavelength to pass through; the wavelengths of the emitted light are thus matched to the infrared absorption spectrum of each gas to be measured. CO_2 is measured at 4.3 μm, N_2O at 3.9 μm and the volatile agents between 10.3 and 13 μm. The filters are positioned on the measuring cell to match the pulses of radiation emerging from the chopper wheel so that each infrared wavelength is modulated at a separate frequency.

Oxygen

This measurement is based on the paramagnetic property of oxygen. When a gas containing oxygen is passed through a switched magnetic field, the gas will expand and contract causing a pressure wave proportional to the concentration of oxygen present. In the 1304, the frequency at which the magnetic field oscillates is different from the pulsation frequencies of the incident infrared radiation in the PAS chamber, so the resulting oxygen signal can be detected by the same microphone as is used for the other gases and the vapour. However, it is necessary to compare the oxygen signal to a reference signal in order to cancel out measurement errors caused by the magnetic field itself.

Signal processing

The multigas signal from the microphone is composed of four different pressure signals, arising from the CO_2, O_2, N_2O, and anaesthetic agent respectively. As the light entering the measuring chamber is modulated to contain three different frequencies, and as the magnetic field used for O_2 oscillates at a fourth frequency, electronic filtering of the multigas signal makes it possible to distinguish between its four component parts.

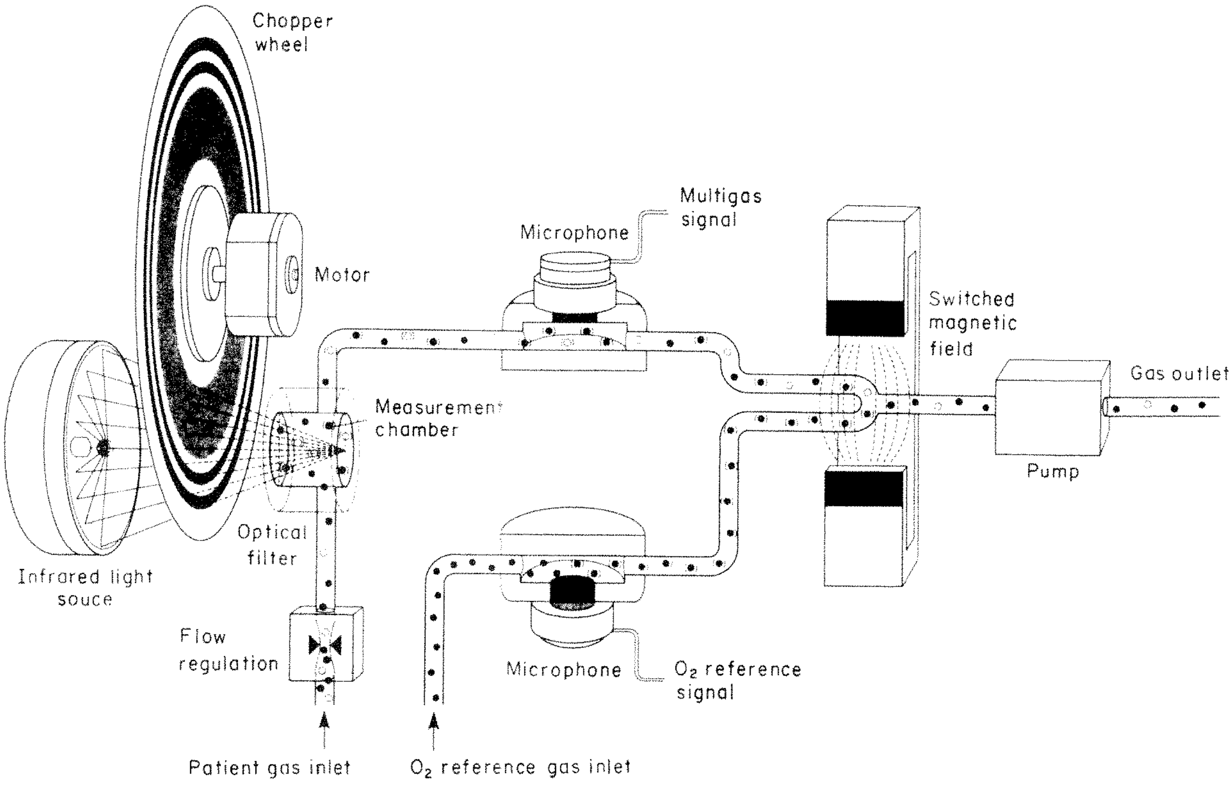

Fig. 2. A diagram of the measurement system.

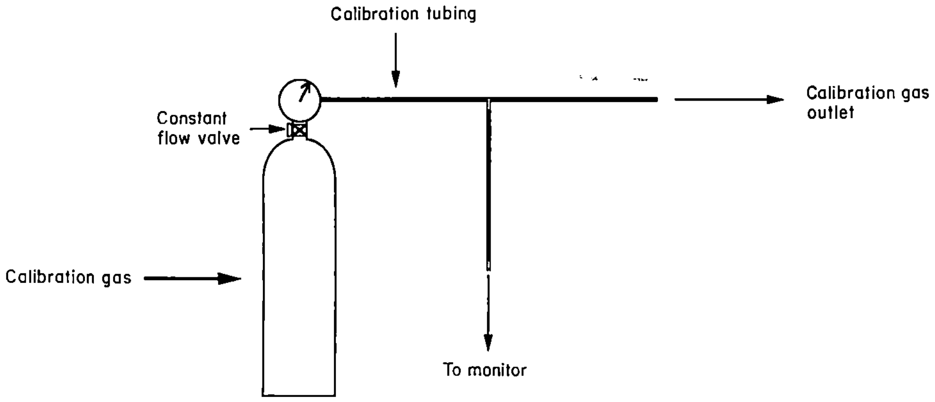

Fig. 3. The set-up used to calibrate the monitor.

Calibration

It is recommended that the 1304 should be calibrated at monthly intervals using the Brüel and Kjær calibration gas QA 0207, containing 47% O_2, 47% N_2O, 5.6% CO_2 and 0.4% SF_6, a constant flow valve QA 0208 and calibration tubing UD 5042 (Fig. 3).

The calibration option is selected from the technical set-up menu, and the appropriate anaesthetic agent is selected, (if the QA 0207 cal gas is used, 'substitute' is selected). The next menu enables the user to adjust the barometric pressure and input cal values; these are the known gas concentrations taken either from the QA 0207 or from another verified source. The flow regulator is then opened and after about 30 s the readings in the 'measured' field stabilise. Any discrepancies can now be corrected. When the calibration is complete the 'set-up' key is pressed and the new calibration values are stored. Various menu pages take the user through the calibration process, each page containing a number of commands.

Laboratory evaluation

The evaluation was carried out on an instrument loaned by the suppliers. The instrument was tested for the following: accuracy in measurement of gas and vapour concentrations; effect of water vapour; response and delay times, frequency responses, effect of alcohol on measurements, effect of cyclopropane on the vapour channels; offset and gain stability. The calibration of the monitor was checked at regular intervals using the 0207 calibration gas.

Accuracy

The accuracy of the monitor was checked using known concentrations of CO_2 in the 0–10% range, with air, O_2 and O_2/N_2O mixtures as carrier gases. For the accuracy of O_2, known concentrations of O_2 in N_2O and O_2 in N_2 were used. The N_2O channel was checked using O_2 as the carrier gas. All the measured and carrier gases were generated by a Wösthoff gas mixing pump which is accurate to 0.02 vol% for concentrations between 0 and 10% v/v and to 0.06 vol % between 10 and 100% v/v. For testing the accuracy of the vapour measurements, various concentrations of each vapour in O_2 and O_2/N_2O mixtures, were generated by passing the carrier gas through PPV vaporizers (Penlon Ltd.) for halothane and isoflurane and an Abbott vaporizer for enflurane. Concentrations of O_2 N_2O, N_2 and anaesthetic agents were measured simultaneously with an eight-channel quadrupole mass spectrometer (Centronic MGA 200). The mass numbers used were 28 for nitrogen, 32 for oxygen, 44 for nitrous oxide and 117, 51 and 51 for halothane, isoflurane, and enflurane respectively. A subtraction box, similar to that described by Davis and Spence [1] was used to correct for the interference by N_2O on the N_2 and O_2 channels. The calibration of the O_2 and N_2 channels was performed using room air and that of the N_2O with 100% v/v N_2O. The subtraction box was set up using 100%v/v N_2O and these three channels were then switched into ASC (automatic sensitivity control) mode. This corrects for any drift in the overall gain of the instrument and adjusts the output of each channel proportionally so that the total is 100%. The calibration of the vapour channel was performed by supplying a mixture of a nominal 2% v/v of vapour in oxygen. This mixture was analysed using a Riken refractometer. If the vapour concentration was x the mass spectrometer was set to read 100x/(100-x) whilst the vapour channel was out of ASC. The channel was then switched into ASC and the reading became x%. The calibration was checked at different vapour concentrations to ensure that the mass spectrometer's response was linear to within 0.1% v/v.

The refractometer used was calibrated by the manufacturer to read halothane in oxygen. The calibration factor for any other agent in oxygen is proportional to the difference between its refractive power and that of oxygen. Calibration factors for the other agents were therefore calculated using the refractive power values shown in Table 1.

Table 1. Refractive powers, at 760 mmHg, 22°C, used to calibrate refractometer.

Halothane	1456
Enflurane	1425
Isoflurane	1420
Nitrous oxide	472
Oxygen	252

Offset and gain stability

The long-term gain stability was checked by calibrating the 1304 with the manufacturer's calibration mixture, and then

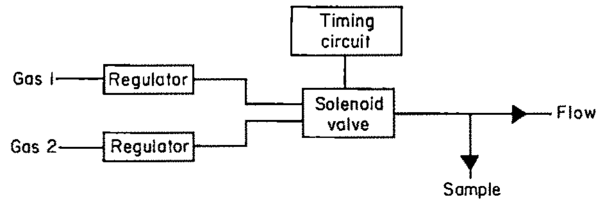

Fig. 4. The set-up used to measure response and delay times.

checking the values after one month, during which the monitor had been used on a daily basis in the operating theatres.

The short term stability was checked by daily calibration of the monitor.

Response and delay times

We defined the delay time as the time between the actual change in gas concentration and the beginning of the change in concentration as recorded by the monitor, although an alternative definition is the time to the achievement of 10% of a step change in the concentration.

The response time was defined as the 10–90% signal rise time.

The response and delay times were determined by creating a square wave change in gas concentration using a three-way solenoid valve (Fig. 4). The movement of this valve could be controlled by an electronic timing circuit which enabled square wave changes of gas concentration to be produced at frequencies from 0–60 breaths.min^{-1}. The high and low gas concentration mixtures were connected to the two inlet ports of the solenoid valve at equal pressures. The gas issuing from the solenoid valve was sampled with the standard sampling tube recommended by the manufacturers and also using a hybrid tube consisting of 16 cm nafion and 80 cm polyethylene, via a T-piece. The composition of the gas mixtures used is shown in Table 2.

At present there are no analogue output signals from the instrument corresponding to gas concentrations. However, the instrument does have an RS232 interface. The default function of this serial port is to send pre-formatted text to a printer, but the instrument can be re-configured to communicate with intelligent devices and may be fully controlled remotely. The gas and anaesthetic agent concentration data can also be transmitted using a proprietary protocol and this was used to measure the delay times and frequency response.

An IBM-AT type computer was used to control the monitor, log the concentration data to disc and monitor the state of the solenoid valve in order to synchronise the incoming data with change in concentration. The RS232 port from the instrument was connected to COM1: of the computer and the state of the solenoid was monitored via a digital input expansion card constructed within the department. In order to achieve an adequate data rate, raw gas concentration data is transmitted in a binary format at 9600 baud without hardware or software handshaking. A program written in Turbo Pascal 5.5 was written to configure the monitor, log the gas data to disc in an ASCII format together with the solenoid state and provide a digital read-out on the computer screen for the current concentrations.

Table 2. Gas mixtures used to test response and delay times.

Channel tested	Gas 1	Gas 2
Oxygen 1	100% O_2	100% N_2
Oxygen 2	100% O_2	100% N_2O
Carbon dioxide	100% O_2	5% CO_2 /95% O_2
Nitrous oxide	100% O_2	100% N_2O
Vapour	100% O_2	97% O_2/3% halothane

The binary output from the monitor is sent every 90 ms and this time was assumed to be the sample interval of the data. The data was converted to a format that would facilitate its analysis by a spreadsheet program.

Frequency response

The frequency responses were determined by switching the valve at gradually increasing frequencies and measuring the highest and lowest concentrations recorded at each frequency.

Interference by water vapour

The effect of water vapour was assessed by using the same gas mixtures as those used to measure accuracies, but these were saturated to > 90% with water vapour. This was achieved by leading the gases (derived from a Wösthoff pump) through an Adams tonometer filled with water at 37°C. The vapour mixtures were bubbled through a spiral coil humidifier from Radiometer blood gas apparatus as this had less resistance to flow [2]. The relative humidity of the mixture issuing from the humidifiers was measured using Solomat relative humidity meter (model:MPM 500E) and found to be close to 93%.

Effect of alcohol

Since some other infrared vapour analysers are affected by alcohol, the sensitivity of the vapour channel to alcohol was tested by holding a swab soaked in absolute alcohol close to the sampling catheter and noting the reading.

Effect of cyclopropane

The effect of cyclopropane on the vapour channel reading was measured by supplying a mixture containing 1% v/v cyclopropane in nitrogen to the instrument via a Wösthoff pump whilst it was switched to the halothane channel. Since cyclopropane is soluble in the pump oil the reading was noted after a steady level was reached (this took approximately 5 min).

Effect of sevoflurane

Sevoflurane from a PPV vaporizer (on loan from Penlon Ltd) was supplied to the instrument in varying concentrations with oxygen as the carrier gas. Since we did not have any data on the refractive index of sevoflurane, we assumed that the vaporizer calibration was accurate and used a flow rate of 4 l.min^{-1} which is close to that used by the manufacturers when calibrating the vaporizer. The reading of the vapour channel at each dial setting was noted.

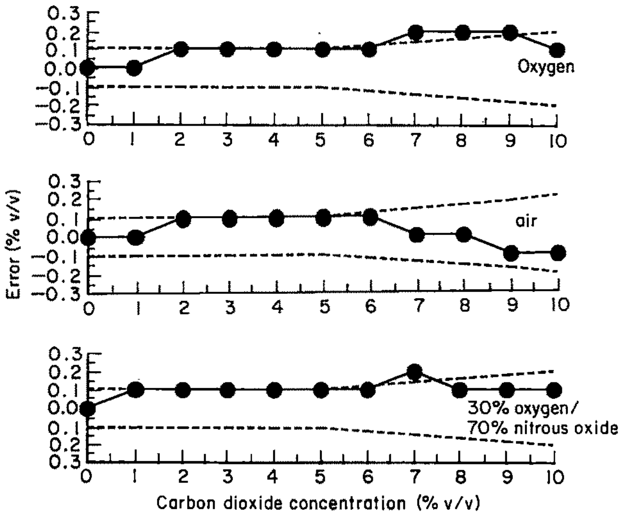

Fig. 5. A comparison of the monitor readings against the actual concentration of CO_2 in air, O_2, and 30% O_2/70% N_2O. The dotted lines represent the manufacturer's specification.

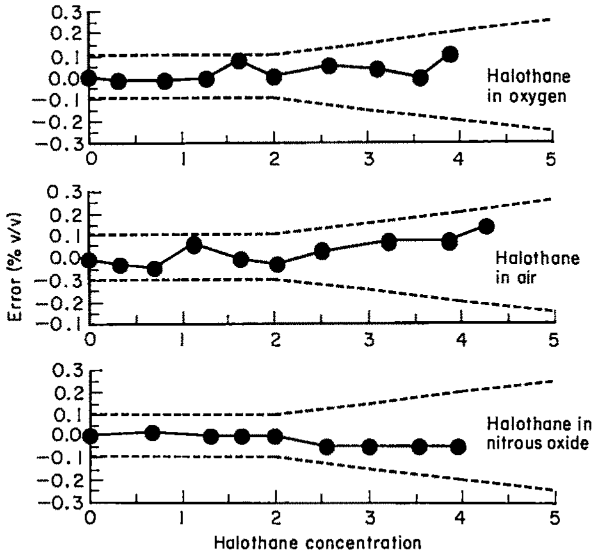

Fig. 7. A comparison of the instrument readings against the actual concentration of halothane in O_2, air and 30% O_2/ 70% N_2O.

Relative sensitivities

Enflurane in oxygen was supplied to the instrument and the reading on the vapour channel was noted. The vapour selected was then changed to isoflurane and then to halothane and the readings were noted.

Results

A comparison of the readings of the monitor against the actual concentration of CO_2 in air, O_2 and 30% O_2/70% N_2O is shown in Figure 5.

The accuracy of the readings was always within the specification for CO_2 in air but with the other gases some readings at the higher concentrations were just outside the specification.

Figure 6 shows the accuracy of oxygen and nitrous oxide concentration readings. The nitrous oxide was mixed with oxygen and the oxygen was also mixed with nitrogen. All the readings were accurate to 1% v/v (SD) which is within the instrument's specification.

Figures 7, 8 and 9 show the accuracy of the volatile agent measurements. The accuracy of all the measurements was within the specifications.

Zero and gain stability

The zero of the gas and volatile agent readings was unchanged during the whole of the trial period. After one month's clinical use the instrument's calibration was checked by supplying gas from the calibration canister. Table 3 shows the actual concentration readings for oxygen, nitrous oxide, carbon dioxide and the anaesthetic agent against the values supplied from the canister.

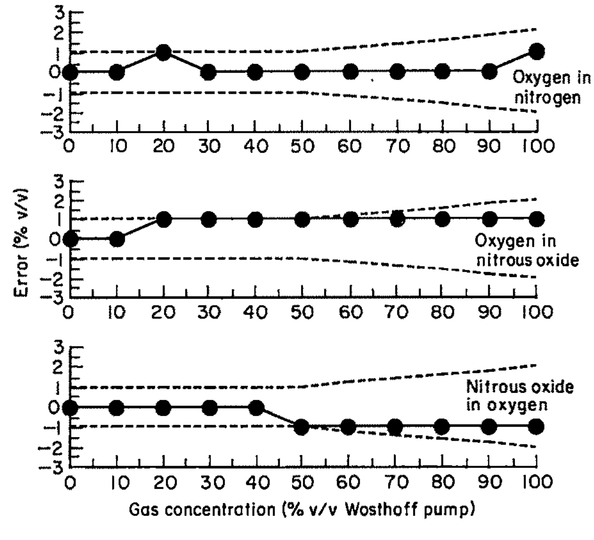

Fig. 6. A comparison of the instrument readings against the actual concentration of O_2 in N_2 and N_2O, and also against the actual concentration of N_2O in O_2.

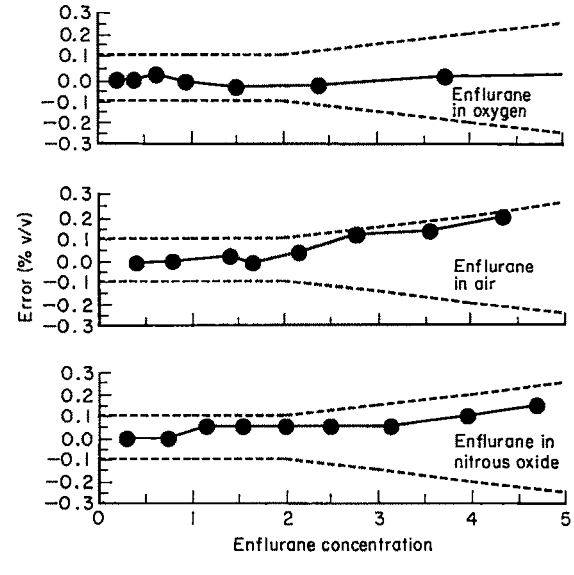

Fig. 8. A comparison of the instrument readings against the actual concentration of enflurane in O_2, air and 30% O_2/ 70% N_2O.

Table 3. Measurements using calibration gas before and after clinical use of the instrument for one month.

Gas	Actual concentration	B and K reading after one month
Oxygen	47	47
Carbon dioxide	5.6	5.6
Nitrous oxide	47	49
Vapour	2.0	2.05

Response and delay times

The response and delay times are shown in Table 4. Since values were only output via the RS232 every 90 ms these values can only be quoted to 90 ms (SD). It was thus not possible to compare them accurately with the specification. However, the figures obtained were in broad agreement with the specification when the nafion tube was used. The results when using the hybrid tube show that it has a greatly increased response time for the anaesthetic agents due to adsorption on the surface of the polyethylene portion of the catheter. Figures 10 and 11 show the percentage response of the instrument to square wave changes in gas composition at frequencies from 5 to 60 breaths.min^{-1} using the nafion and hybrid tubes respectively.

With both the nafion and the hybrid tubes fitted, the instrument gave a response better than 90% for O_2, N_2O and CO_2 at frequencies up to 60 breaths.min^{-1}. For halothane a 90% response was maintained up to 40 breaths.min^{-1} with the nafion tube, but only up to 20 breaths.min^{-1} with the hybrid tube. The zero levels were always less than 10% full scale when the nafion tube was used. However, with the hybrid tube the zero levels were greater than 10% for the halothane measurements when the breathing frequency was greater than 10 breaths.min^{-1}.

Effect of water vapour

The addition of water vapour to the gas and vapour mixtures had no effect on the measured gas concentrations and the sampling line was not occluded during the performance of these tests.

Table 4a. Reponse and delay times with the nafion sampling tube.

Gas	Delay(s)	Response (ms)
O_2 in N_2	2.25	< 360
O_2 in N_2O	2.43	< 270
N_2O in O_2	2.97	< 270
CO_2 in O_2	2.52	< 360
Halothane in O_2	2.61	< 360

Table 4b. Response and delay times with the hybrid tube.

Gas	Delay(s)	Response (ms)
O_2 in N_2	3.33	< 360
O_2 in N_2O	2.97	< 270
N_2O in O_2	2.97	< 270
CO_2 in O_2	2.52	< 360
Halothane in O_2	4.41	< 2880

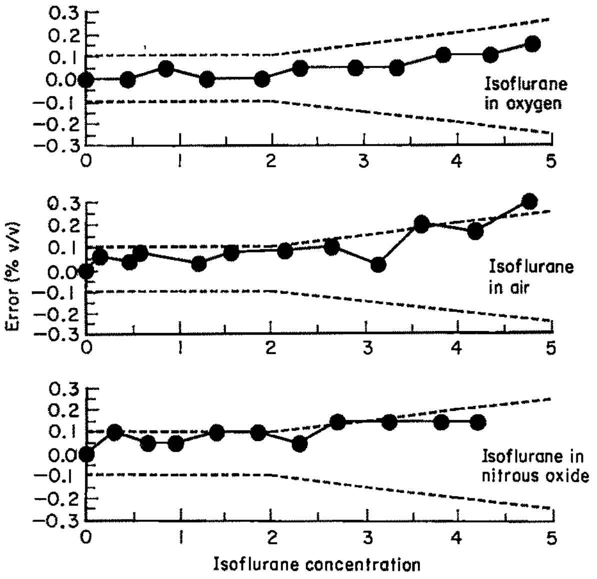

Fig. 9. A comparison of the instrument readings against the actual concentration of isoflurane in O_2, air and 30% O_2/ 70% N_2O.

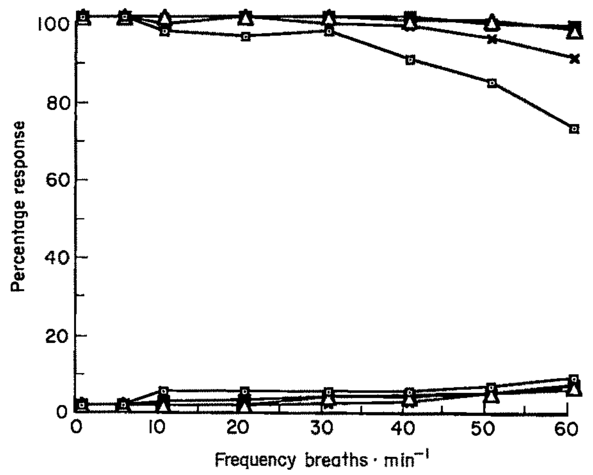

Fig. 10. Percentage response (maximum and minimum) of the monitor to square wave changes of gas composition at various breathing frequencies when the nafion sampling tube was used. ■, nitrous oxide; △, carbon dioxide; X, oxygen, ⊡, halothane.

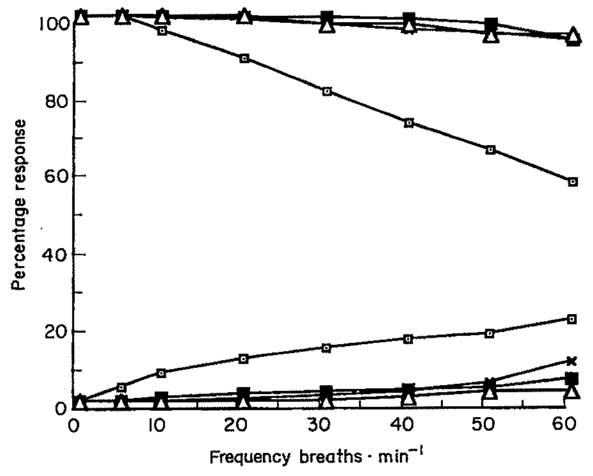

Figure 11. Percentage response (maximum and minimum) of the monitor to square wave changes of gas composition at various breathing frequencies when the hybrid sampling tube was used. ■, nitrous oxide; △, carbon dioxide; X, oxygen; ⊡, halothane.

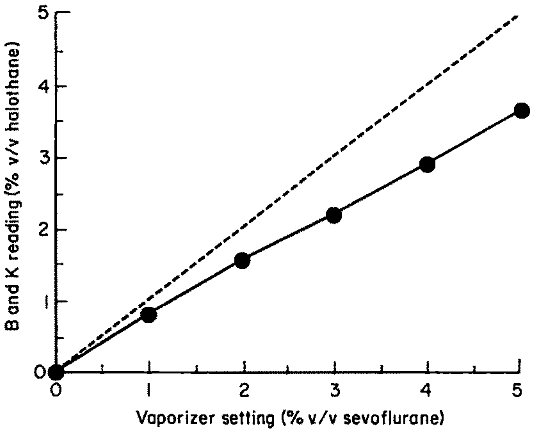

Fig. 12. Monitor reading (% v/v halothane) vs concentration of sevoflurane (% v/v) supplied from a Penlon PPV vaporizer.

Effect of alcohol

Sampling alcohol vapour from a swab soaked in absolute alcohol did not produce any reading on the vapour channel.

Effect of cyclopropane

When 1% v/v of cyclopropane in nitrogen was supplied the reading on the vapour channel with halothane selected was 0.4%.

Effect of sevoflurane

Figure 12 shows the reading of the monitor when halothane was selected as the vapour but sevoflurane was supplied via a Penlon PPV vaporiser.

Relative sensitivities of vapour channels

When 1.85% v/v enflurane was supplied to the instrument and the vapour selected was changed to halothane and then to isoflurane the readings were 2.55 in both cases.

Discussion

This instrument can follow breath-by-breath changes in O_2, N_2O, CO_2 and anaesthetic vapour. It also has an integral pulse oximeter. The Datex Capnomac is capable of providing the same gas analyses, but the B and K instrument has certain advantages. First because the instrument uses the same microphone for detection of all the gases, it displays the gas concentration graphically with a real-time relationship. Second, the wavelength used for measurement of anaesthetic vapours is at the high end of the infrared spectrum (10.3–13 μm) rather than at 3.3 μm, which is the wavelength used in the Capnomac. The relative absorption is similar for all the agents at the high end of the spectrum [3] so that if the wrong vapour is accidently selected, the error in the reading will not be very great. At 3.3 μm the sensitivity to halothane is much lower so that a high gain factor needs to be used, with resultant loss of accuracy. Other sources of inaccuracy in the vapour concentration measurement are interference by alcohol in the patient's expired breath [4] and by cyclopropane [5]. Alcohol does not affect the vapour readings on the 1304 and the effect of cyclopropane is much lower than with the Normocap (1% v/v cyclopropane reads 0.4% on the halothane or isoflurane scales and this corresponds to 0.3% on the enflurane scale). The corresponding figures for the Normocap are 14.3, 2.2 and 2.7.

Although the accuracy of the gas concentration readings is somewhat greater than for the Capnomac [6] this difference is not of significance in clinical practice. The response times for the gases are similar to those for the Capnomac so that there is a satisfactory response at all adult breathing frequencies provided that the nafion tube is used. The vapour response when using the nafion tube is better than that of the Capnomac. However, that obtained with the hybrid tube is considerably worse and illustrates the necessity for the additional expense incurred in using a sampling tube made entirely of nafion.

The instrument's zero and gain are both very stable. During the whole assessment period the zero level on all channels remained stable and the change in the gain over one month was not clinically significant thus verifying the manufacturer's claim that the instrument need only be calibrated monthly.

The instrument was subjected to a brief clinical trial and performed satisfactorily during that period. Most anaesthetists commented favourably on the instrument's ease of use. However, a number felt that the absence of an audible bleep on the pulse oximeter was a disadvantage and it was felt that more prominence should be given to the display of O_2 saturation measurement.

Since the performance of this assessment we have been informed by the manufacturers that from May 1991 the instrument has incorporated an audible beep on the pulse oximeter as a standard feature and an analogue output will be available as an option. It will also incorporate a pressure sensor so that there will be no need to enter the barometric pressure during the calibration procedure.

Acknowledgments

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APPARATUS

Initial evaluation of an intracorporeal oxygenation device

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Summary

We describe a recently developed intracorporeal gas transfer device, its potential applications and hazards. To date, patients with potentially reversible respiratory failure have been treated with controlled oxygen therapy and positive pressure ventilation, but this treatment may itself contribute to lung parenchymal damage from barotrauma and oxygen toxicity. Total or partial extracorporeal gas exchange can be used to reduce these risks, but this treatment is complex and has significant morbidity and mortality. This gas exchange device has been designed to provide partial gas transfer with simplicity of insertion and use. The oxygenator lies in the vena cava to provide prepulmonary gas exchange. In preliminary studies with three calves we have shown that the device increases both mean mixed venous and arterial oxygen content and reduces mean arterial carbon dioxide tension.

Key words

Equipment; intracorporeal oxygenator.

Description of the apparatus

A new intracorporeal and intravascular blood gas exchange device IVOX [1] (Cardiopulmonics Inc., Salt Lake City, Utah) is currently undergoing multicentre clinical trials under an investigational device exemption issued by the United States Food and Drug Administration [2]. This equipment has been developed to augment gas exchange by conventional positive pressure ventilation [3]. The IVOX consists of a polypropylene multiple fibre oxygenator (internal diameter 200 μm) placed in the vena cava for prepulmonary blood gas exchange (Fig. 1) through a single surgical venotomy.

Each external fibre surface has a siloxane gas-permeable membrane coating [4] less than 1 μm thick and is treated with covalently bonded heparin to reduce potential thrombogenicity. The fibre arrangement is crimped so that turbulent blood flow over the device enhances gas transfer [5].

The IVOX is available in four adult sizes (Table 1) so that the largest possible can be used in each case without venous endothelial trauma.

A controlled vacuum regulates an oxygen flow of between 1 and 3 $\mathrm{l.min^{-1}}$ through the apparatus. This minimises the risk of vascular gas embolism if fibre rupture were to occur. Co-axial double lumen tubing permits gas circulation within the oxygenator through a single venotomy site. Gas flows through the inner lumen towards the oxygenator tip and then into the hollow fibres.

Insertion

Right internal jugular or femoral veins are recommended as insertion sites for the device. Pulmonary artery catheterisation, if required, must preceed IVOX insertion, otherwise entanglement within the oxygenator fibres may occur. An intravenous introducer sheath is inserted under asepsis, after direct venotomy. Selection of an oxygenator of the largest size is then possible using dedicated vein size templates. The fibre oxygenator is prepared for insertion within a hydration tube containing heparinised saline. This releases trapped air from the external fibre surface to minimise the risk of air embolism. An external furling device and stiffener are attached and the IVOX fibres furled to a more compact arrangement to permit ease of insertion.

Table 1. Oxygenator dimensions.

Product size	7	8	9	10
Length; cm	30	33	37	40
Furled diameter; Fr	38	41	46	48
Surface area; m^2	0.20	0.26	0.36	0.5

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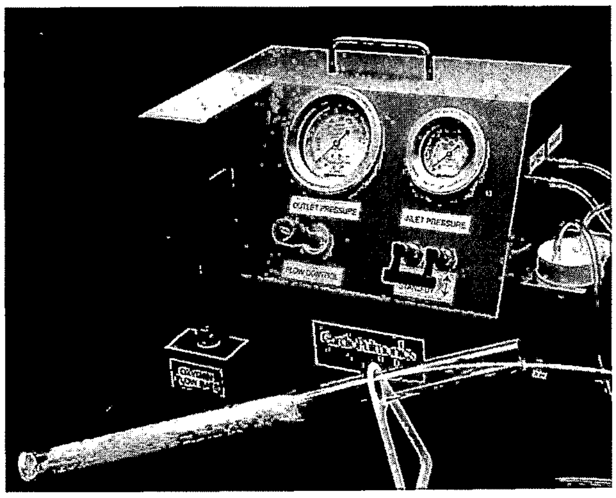

Fig. 1. The IVOX apparatus. In the foreground is the fibre oxygenator within the hydration tube. The gas controller is in the background.

After the gas conduits are connected and the gas controller adjusted for adequate gas flow, gas leakage across the oxygenator is checked to prevent potential gas embolism. No moisture should appear at the IVOX gas outlet channel; this would indicate a fibre leak. A subatmospheric pressure of 300 mmHg is applied to the oxygenator and then both gas channels are occluded. Failure to maintain this vacuum would also indicate fibre leakage.

To introduce the IVOX a guidewire is advanced through the introducer sheath under image intensifier control. A femoral approach requires the wire tip to be advanced to the level of the first rib (within the superior vena cava) and an internal jugular approach necessitates advancement until the wire tip reaches the inferior caval bifurcation (level of third lumbar vertebral body). The furled IVOX is then advanced over this guidewire and its site within the right atrium and caval system confirmed. The wire is then removed and the device unfurled (Fig. 2).

Method

The research was registered with the Home Office and performed under the Animals (Scientific Procedures) Act 1986. Following 24 h starvation, general anaesthesia was induced with xylazine (0.3 mg.kg^{-1}), thiopentone (1–2 mg.kg^{-1}) and pancuronium (0.1 mg.kg^{-1}) in three cross-bred Fresian calves whose mean weight was 103 kg. Anaesthesia was maintained by ventilation to normocapnia with 50% nitrous oxide in oxygen and 1% isoflurane through a circle breathing system. Rumenal distension was prevented by a gastric tube, and intravenous fluids were given to replace upper gastrointestinal tract losses and maintain intravascular filling pressures.

Femoral arterial, central venous and pulmonary artery pressures were monitored. Cardiac output was measured by thermodilution and continual mixed venous oxygen saturation assessed by reflectance spectrophotometry (Edwards SAT-2). In addition ECG, $F\text{E}'\text{co}_2$, $F\text{IO}_2$ and $F\text{E}'\text{O}_2$ oxygen (Datex) were monitored. Arterial and mixed venous oxygen saturation was measured (OSM 2 Hemoximeter, Radiometer), as was pH and gas tensions (ABL-2 Radiometer). Oxygen saturation values obtained from this calibrated oximeter were then used to calculate blood oxygen content and to perform an *in vitro* calibration of the reflectance spectrophotometer. At 30 min intervals throughout the investigation venous samples were taken for full blood count and biochemical analysis.

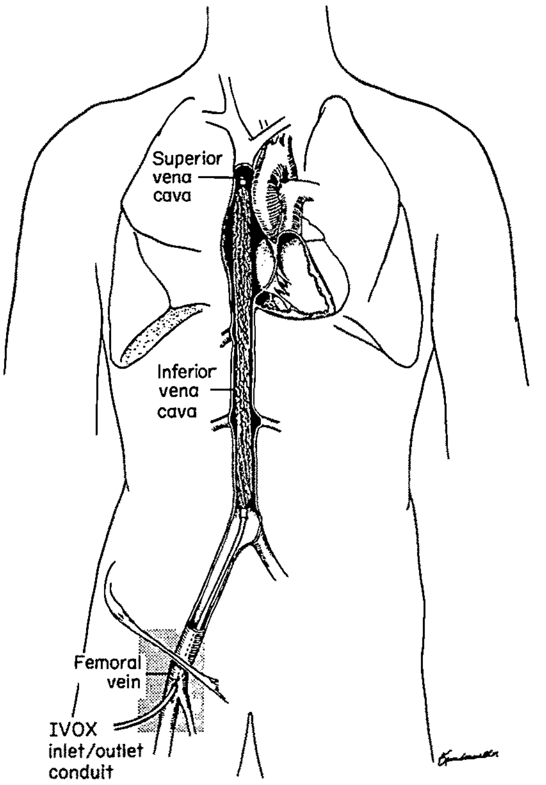

Fig. 2. The IVOX fibre oxygenator *in situ* within the caval venous system.

Each calf had a right internal jugular venotomy and a size 7 IVOX inserted under radiographic guidance. Systemic anticoagulation was with heparin (300 IU.kg^{-1}). Function was evaluated at maximal IVOX gas flow of 2.8 l.min^{-1} with an $F\text{IO}_2$ of 0.11.

Results

Carbon dioxide elimination

A reduction in mean arterial CO_2 tension was observed during use of the IVOX under conditions of normocapnia (Table 2 and Fig. 3).

Oxygenation

Figure 4 is a sample trace of mixed venous saturation, as measured by continuous reflectance spectrophotometry, against time. Ventilation with an $F\text{IO}_2$ of 0.11 produced a stable venous saturation of 28% within 15 min which then

Table 2. Blood gas parameters: effect of IVOX activation.

	IVOX off mean (SEM)	IVOX on mean (SEM)
$P\text{aco}_2$; kPa	5.23 (0.28)	4.70 (0.36)
$C\text{ao}_2$; ml.dl^{-1}	8.07 (0.22)	9.61 (0.08)
$C\bar{\text{v}}\text{o}_2$; ml.dl^{-1}	4.17 (0.08)	5.04 (0.01)

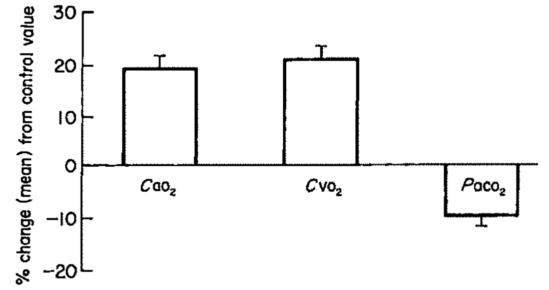

Fig. 3. The effect of IVOX activation on blood gas parameters.

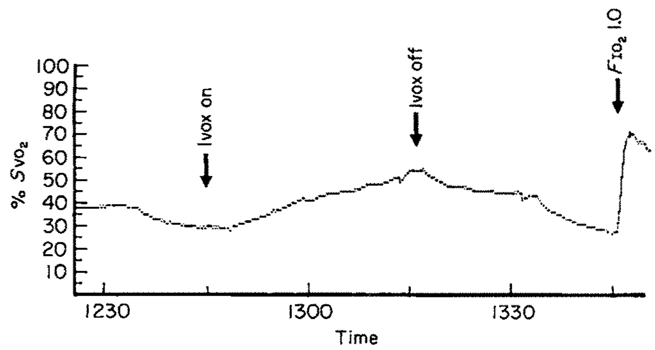

Fig. 4. Illustrates the effect of IVOX activation upon SpVO$_2$ during induced hypoxaemia (FiO$_2$ 0.11).

increased to 53% over 30 min when the oxygenator was activated.

Table 2 demonstrates that use of the IVOX was associated with an increase in both mean mixed venous oxygen content ($C\mathrm{vo}_2$) and arterial oxygen content ($C\mathrm{ao}_2$) (Fig. 3) during induced hypoxaemia.

Haemodynamic and metabolic parameters

Insertion of the IVOX caused no significant change in haemodynamic variables or cardiac rhythm disturbance. However, induced hypoxaemia did increase mean pulmonary arterial pressure which was reduced by IVOX activation (Fig. 5). In addition there was no significant change in haematological (Table 3) or biochemical variables during the 400 min study.

Discussion

In this calf model there was a small increase in oxygen uptake when the intracorporeal oxygenator was used during extreme hypoxaemia. The partial reversal of hypoxia-induced rises in pulmonary arterial pressure when the IVOX was used suggests that some physiological significance can be inferred from the small increases produced in $C\mathrm{vo}_2$ and $C\mathrm{ao}_2$.

Table 3. Haematological data.

Time (min)	Red cell count mean (SEM) $10^{12}.l^{-1}$	Platelet count mean (SEM) $10^{9}.l^{-1}$
0	7.77 (0.35)	522 (80)
100	7.94 (0.38)	565 (86)
200	7.81 (0.53)	549 (75)
300	7.75 (0.34)	611 (7.0)
400	7.88 (0.40)	603 (12)

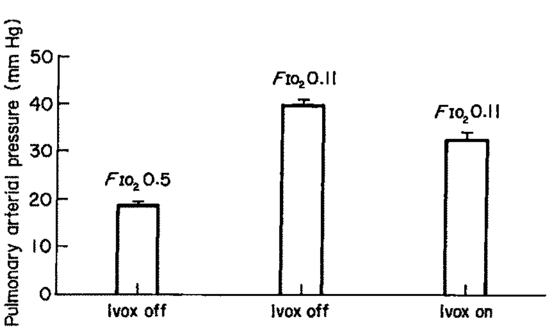

Fig. 5. The effect of IVOX activation on mean pulmonary arterial pressure (mmHg).

A fall in $P\mathrm{aco}_2$ was demonstrated when the IVOX was in use. Experimental insertion of these oxygenators has not previously been performed in the calf, although its suitability as a model for cardiovascular research is well described [6]. The calf is a relatively docile animal to handle and has thoracic and cardiovascular basal indices similar to man's. However, despite the relatively high body mass, compared to man, it was not possible to site an oxygenator of greater than 0.20 m^2 surface area because of anatomical variations within the jugular venous system. This therefore limited maximum possible gas exchange.

It has been shown in dogs and sheep (up to 60 kg) [1, 3] that it is possible to site oxygenators of up to 0.60 m^2 surface area with transfer rates of 204 ml O_2.min^{-1} and 252 ml CO_2.min^{-1}.

Compared with extracorporeal gas exchangers with surface areas in excess of 10 m^2 an intracorporeal device will necessarily be limited in performance by size. In addition to increased surface area external devices use higher gas flows (6 l.min^{-1}) and have better ventilation/perfusion ratios. An increased 'capillary transit time' through the extracorporeal oxygenator interface also improves blood oxygenation [7].

Because of these limitations it is unlikely that an IVOX could offer the same support as with an extracorporeal membrane oxygenator [8, 9]. Partial pulmonary support can be achieved with an extracorporeal carbon doxide removal circuit [10] and it is possible that the IVOX could provide a similar degree of gas transfer. No significant change in biochemical or haematological parameters was detected during the 400 min study period, and with systemic anticoagulation the IVOX has been in use without adverse effects in sheep for up to 19 days [2]. This contrasts with extracorporeal circuits which incorporate a higher surface area of potentially thrombogenic material. These have an adverse effect upon all cellular components, especially decreased platelet count and impaired function [11] leading to impaired haemostasis. Extended use of an IVOX may not be associated with the severe haemorrhage that frequently accompanies extracorporeal lung assistance. The decreased surface area of the IVOX will reduce heat losses relative to external circuits and may also decrease the incidence of sepsis secondary to microbial colonisation. Complex extracorporeal circuits pose technical problems in interhospital transfer [12]. In contrast, the relatively simple IVOX would not require a heavy electrical load and the absence of an external circuit would reduce heat losses. The

IVOX could have a role in augmentation of conventional positive pressure ventilation and enable the maintenance of normal blood gas tensions while avoiding pulmonary barotrauma associated with high lung inflation pressures and positive end-expiratory pressure [13, 14]. This device may permit the use of lower inspired oxygen tensions and minimise the adverse effects of higher oxygen tensions [15] on pulmonary gas transfer and compliance. The use of the IVOX in high mortality patient groups requires careful evaluation to determine if it actually contributes to improved outcome.

Acknowledgments

Financial assistance for this project was provided by British Petroleum PLC. Figure 2 was reproduced with permission of Actamed Ltd. (Wakefield).

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Anaesthesia, 1992, Volume 47, pages 52–53

APPARATUS

Finger blood content, light transmission, and pulse oximetry errors

T. M. CRAFT, R. A. LAWSON AND J. D. YOUNG

Summary

The changes in light emitting diode current necessary to maintain a constant level of light incident upon a photodetector were measured in 20 volunteers at the two wavelengths employed by pulse oximeters. Three states of finger blood content were assessed; exsanguinated, hyperaemic, and normal. The changes in light emitting diode current with changes in finger blood content were small and are not thought to represent a significant source of error in saturation as measured by pulse oximetry.

Key words

Equipment; pulse oximeter.
Haemoglobin; anaemia.

Light emitting diodes (LEDs) are used as light sources in pulse oximeters as they produce a narrow band of wavelengths. The stability of the emitted wavelengths is critical to the accuracy of pulse oximeters as the absorption spectra of reduced and oxygenated haemoglobin exhibit large changes for small changes in wavelength. A change in LED wavelength during the operation of a pulse oximeter may thus result in inaccurate oximeter readings. For example, if the wavelength of the red LED is decreased, the absorption of red light by reduced haemoglobin increases, resulting in an apparent fall in saturation as measured by the oximeter.

Severinghaus and Koh have recently shown that pulse oximeters under-read at low saturations [1] and speculated that at low saturations the relatively high absorption of red light causes a reduction in the amount of red light incident upon the detector (photodiode). Pulse oximeters alter the intensity of their LEDs according to the thickness and optical density of the finger or earlobe in order to maintain the intensity of light reaching the photodiode in a narrow range. A reduction in red light transmission thus leads to an increase in current at the red LED. These authors suggest that this heats the diode and results in a reduction of the peak wavelength of light emitted by the LED. This in turn causes the oximeter to under-read at low saturations. Paradoxically, this is worse in anaemic subjects.

This explanation for pulse oximeters under-reading at low saturations seems unlikely to be correct for two reasons. Firstly, blood represents only a small proportion of the tissue of the finger or ear. Unless blood is the major light absorbing component of tissue, it is unlikely that changes in saturation will alter the total light absorption of the finger or ear sufficient to cause major changes in LED current. Secondly, increasing LED output from 10% to 100% of the manufacturer's maximum specified current has been shown to increase, not decrease, the peak wavelength. This increase in wavelength amounted to only 8 nm when LED current was increased ninefold [2].

The contribution of blood to the total optical density of the finger has not been evaluated. The following study was undertaken to assess our hypothesis that the level of haemoglobin in the finger has no effect on LED current and is thus unlikely to affect pulse oximeter accuracy.

Methods

Changes in light absorption were measured using a locally made two-wavelength photometer designed to mimic a pulse oximeter probe. Two LEDs with peak wavelengths of 635 nm and 950 nm were applied to the dorsal surface of the finger overlying the nail. A photodiode was placed on the ventral aspect of the finger opposite the LEDs. Only one LED was illuminated at a time. LED current was controlled by a potentiometer and monitored with a digital ammeter. The current from the photodiode (a measure of the light incident upon it) was amplified and converted to a voltage which was displayed on a digital voltmeter.

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Measurements of light absorption were taken with the finger in the photometer inside a light-tight box. The red LED (635 nm) was switched on and the current adjusted until the photodiode voltage reached a value corresponding to an incident light intensity of 1.9 lux. This current was recorded and the procedure repeated using the infra-red (950 nm) LED.

Measurements were made in 20 healthy volunteers under three different conditions. Severe anaemia was simulated by exsanguinating the fingers, hand, and arm with an elastic rubber bandage and a tourniquet applied to the upper arm at 300 mmHg. Following measurement of light absorption the tourniquet was released and the ensuing hyperaemia taken to represent maximum tissue blood content. The measurements were repeated and then the third, baseline readings were taken 5 to 10 min later.

Results

In the exsanguinated finger the mean (SD) red (635nm) LED current for all 20 subjects required to maintain a constant intensity of light incident upon the photodetector was 34.7% (7.22) of the manufacturer's rated maximum (30mA). In the hyperaemic state the current was 47.6% (14.14) of maximum and under conditions of normal blood content it was 45.8% (13.5).

The results for the near infrared (950nm) LED show a similar but more exaggerated pattern. The current required in the exsanguinated state was 22.8% (6.17) of the maximum 100mA and under hyperaemic and normal conditions was 35.5% (12.1) and 25.1% (9.8) respectively. These results are represented graphically in Figures 1 and 2.

Discussion

As might be expected, less current is required to maintain a constant level of light at the photodiode under exsanguinated (anaemic) conditions than in either the hyperaemic or normal states. The greatest increase in current required is seen with the near infrared LED under conditions of hyperaemia. This may be because the hyperaemic state was produced by predominantly oxygenated blood and oxyhaemoglobin absorbs a greater amount of light in the infrared spectrum. The maximum current change in this experiment was 13%. This is far less than the 90% changes employed in a previous experiment [2]. We would therefore expect the increase in peak wavelength associated with the increase in LED current in our study to be even smaller than the maximum 8 nm observed by de Kock and his colleagues.

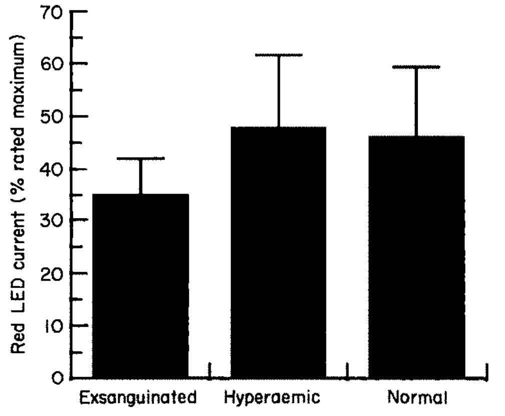

Fig. 1. The mean red LED current as a percentage of its rated maximum required to maintain a constant level of light incident upon the photodetector is shown on the ordinate against the three states of finger blood content. Error bars are standard deviation.

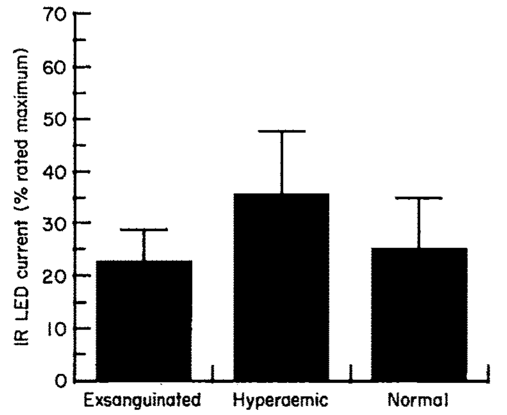

Fig. 2. The results for the infrared LED in the same format as those of the red LED.

If changes in LED output were to produce significant changes in apparent saturation as measured by pulse oximetry we would also expect that for any given true saturation there would be a difference between the saturation at the great toe and that at the fifth finger due to different total absorptions. Apparent desaturation at the toe would be predicted.

In conclusion, changes in the blood content of the finger produce small changes in the current requirements of LEDs in order to maintain a constant level of incident light at the photodiode. These current changes would produce minimal changes in peak wavelength. Changes in finger blood content are thus not a cause of a clinically significant error in pulse oximetry.

Acknowledgement

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Anaesthesia, 1992, Volume 47, pages 54–56

HISTORICAL NOTES

Malignant hyperthermia

An historical vignette

G. G. HARRISON AND H. ISAACS

Summary

This paper reports previously unpublished accounts of the deaths in 1915 and 1919 of two members of the same family during general anaesthesia. The deaths were subsequently ascribed to a 'hereditary susceptibility' to chloroform. Contemporary evidence is presented which suggests that these deaths were among the very earliest examples of malignant hyperthermia to be described.

Key words

History; chloroform.
Complications; death.
Hyperthermia; malignant.

The report by Denborough and Lovell, in 1960 [1], of a family who manifested a strange predisposition to death during general anaesthesia, led ultimately to the identification of malignant hyperthermia (MH) as a clinical pharmacogenetic entity [2]. Subsequent experience has indicated that all volatile anaesthetics, especially the newer halogenated agents as well as chloroform, are capable of triggering the MH crisis in genetically susceptible individuals [3], and this has begged the question why MH had not been noted before 1960 as a genetic entity. Letters that have recently come to light do seem to provide evidence that, some 40 years before Denborough and Lovell's classic description, a Dr G.A. Jones of Buckinghamshire did observe and record an example of such a familial fatal idiosyncrasy to chloroform anaesthesia but, sadly, never published his observations.

In 1987 a 2.5-year-old child died tragically from MH while subjected to general anaesthesia for conservative dentistry of a minor nature. Subsequent muscle biopsy *in vitro* contracture testing (IVCT) of the proband's close family showed the child's father, uncle and cousin (the latter's son) all to be susceptible to MH (MHS). A cousin of the child's grandfather, (Fig. 1 (6)), had believed that members of her family had a strange and dangerous sensitivity to general anaesthetics and a family tree was revealed (Fig. 1) which showed circumstantial evidence of the MHS trait in all four generations. This by itself can no longer be regarded as extraordinary (MHS transmission is autosomal dominant and many such pedigrees have been reported since Denborough and Lovell's original description [1]). However, letters written in 1919 and earlier about the circumstances of the first two deaths during anaesthesia of members of this family, those of Figure 1 (1) in 1915 and her son, (Fig. 1 (3)), in 1919, are of considerable historical interest. The first of these deaths occurred in 1915, but the letters were written in 1919 following the death of this patient's son, when the similar circumstances of the latter's death motivated re-examination of those of the former.

The death of the latter, (Fig. 1 (3)), occurred in February 1919, at Marlborough during an operation for the exploration of a ruptured kidney. The following is an extract from the report submitted by the anaesthetist, Dr E. Penny:

> 'The anaesthetic was chloroform and ether given on an open Schimmelbusch mask and the amount used during the operation was almost exactly one ounce of the former and two ounces of the latter, the duration of the administration being half an hour. The patient, who did not seem at all nervous, passed normally and quickly under the anaesthetic but when the surgeon was about to begin the operation, it was noticed that a curious muscular rigidity existed in the arms, legs and abdominal muscles, the patient being fully under the anaesthetic and breathing quietly and freely. This

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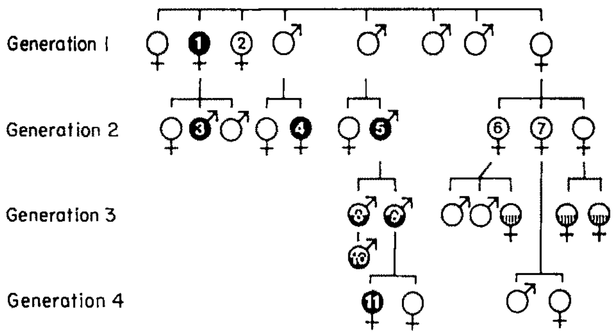

Fig. 1. Genealogical table (abridged). ●, died of malignant hyperthermia (MH) or? malignant hyperthermia; ◒ *in vitro* contracture testing (IVCT) MH susceptible; ◓, IVCT MH negative.

muscular condition persisted during the operation which consisted in the first stage of exploring the peritoneal cavity in front of the injured kidney and in the second stage in cutting down to the kidney from behind. Just as the second stage was being completed a violent and persistent spasm of all the respiratory muscles of the thorax occurred and the movements of the chest ceased suddenly and absolutely. Artificial respiration was at once resorted to but no re-establishment of natural breathing could be obtained, though it was evident no impediment existed to the passage of air through the larynx. The heart continued to beat for a time after the fatal spasm occurred ...'.

On receipt of this report, Dr G.A. Jones of Little Seeleys, Beaconsfield, Buckinghamshire, the anaesthetist concerned 4 years earlier with the death under anaesthesia of this patient's mother, wrote to her husband this letter, from which extracts follow:

> '... Mrs ...'s operation was a rather long one in two stages, the first being abdominal for the fixing of the womb to the abdominal wall and the second vaginal for still further preventing prolapse ... I began with gas and ether but changed to a mixture of chloroform and ether as is usually done in operations of any length. The first stage was done in half-an-hour to three-quarters-of-an-hour, and there was nothing then in the condition to cause the slightest anxiety ... The second stage took about half-an-hour and it was not until near the end that any alarming symptoms showed themselves. There was a marked tendency to spasm of the muscles of the arms and jaw and apparently those of respiration, and the breathing stopped fairly quickly. The condition of the pupils had indicated a medium rather than deep anaesthesia i.e. they were contracted, not dilated as in chloroform overdose. When breathing stopped, the pulse was present though rather rapid. Stimulants and artificial respiration were tried without avail. Tracheotomy was tried as a last resort.
>
> There is a strong similarity in the cases of mother and son as regards the curious rigidity and spasm ... but it is very rare indeed for any spasm of the muscles of respiration to occur. It looks as if in both cases there was a tendency of abnormal rigidity coupled with a susceptibility to chloroform.
>
> The sister of the house told me afterwards that Mrs ... had had attacks of muscular spasm apparently suggesting the condition known as Tetany. ...
>
> The fact of a fatality occurring to both mother and son is very suggestive, but I cannot find any mention of hereditary susceptibility definitely ascertained in the standard text book on Anaesthetics ... One is inclined to advise that the two other children should be thoroughly examined by a first-class physician who might be able to say whether they had anything of the kind, but its a condition very difficult to recognise. I think chloroform should be absolutely barred if an operation were necessary and as little ether given as possible on an open mask after an injection of morphine. Yours sincerely, etc.'

Later, Dr Jones wrote to the 'sister of the house' (Fig. 1 (2)) when she had become the guardian of the remaining children: 'Dear Miss ..., With reference to your nephews, I consider that in view of what occurred in the case of their mother and brother, they should never have chloroform for an operation in any circumstances, but that with either gas and oxygen or ether by the open method preceeded by an injection of Morphia gr 1/6 and atropine gr 1/20 the risks should be practically negligible. Yours &c.'

In 1925 a third member of the family, (Fig. 1 (4)), died while anaesthetised undergoing an appendicectomy. Clinical details of this fatality have been lost. However, this succession of three deaths under anaesthesia in this family led them to take the precaution of showing the above letters to the matron of the Johannesburg Hospital in 1933 when another member of generation 2 (Fig. 1 (7)), entered the nursing profession. Some years later, yet another member of generation 2 (Fig. 1 (5)) (the grandfather of the child whose death motivated this report), died while anaesthetised. In this case, details of which also are now sadly lacking, the patient died immediately postoperatively after a gastric operation.

This family's history begs the question 'Was Jones' fatal familial susceptibility to chloroform indeed MH?' In describing the clinical circumstances associated with the deaths of 1915 and 1919, neither Jones nor Penny make any mention of their patients' body temperature, an omission that could be regarded as invalidating any retrospective diagnosis of MH. Yet it must be remembered that at that time monitoring of the patient's temperature during anaesthesia and surgery was not routine practice, if indeed it was ever recorded at all under these circumstances. Further, both accounts lay particular stress on the appearance of that other cardinal manifestation of MH, muscle rigor, implying that respiration ceased because of the rigidity of the muscles of respiration. Jones also mentions the history given by a 'sister of the house' that her sister had complained of bouts of muscle spasm, a feature well-documented in some subjects of the MHS trait [4].

When the Jones and Penny accounts are considered in the light of objective contemporary evidence of the death from MH of Figure 1 (11), the IVCT-diagnosed MH trait in her father, (Fig. 1 (9)), her uncle, (Fig. 1(8)), and her cousin, (Fig. 1 (10)), together with the histories of the anaesthetic-related deaths of her grandfather, (Fig. 1 (5)), and his cousin, (Fig. 1 (4)), the balance of probability must lead us to conclude that these cases of 'hereditary susceptibility' to chloroform, identified by Jones, were none other than historically very early examples of MH, indeed among the very earliest to be described [2] albeit unpublished till now.

Table 1. Results of diagnostic tests.

Family member	% halothane	Contracture, g.	Caffeine concentration mmol.l^{-1}	Contracture, g.
8	0.5	0	0.5	0.5
	1.0	0.2	1.0	1.3
	2.0	1.3	2.0	> 5.0
	3.0	6.4	3.0	
9	0.5	0	0.5	0.9
	1.0	0.7	1.0	1.8
	2.0	2.8	2.0	> 5.0
	3.0	8.0	3.0	
10	0.5	0	0.5	0.1
	1.0	0	1.0	0.3
	2.0	2.2	2.0	0.8
	3.0	0.5	3.0	1.6

All displayed normal histology and histochemistry.

Appendix, data relevant to Figure 1

MH proband, family member Figure 1 (11), died during anaesthesia with halothane and nitrous oxide/oxygen approximately 45 min after the onset of a fulminant episode of MH, which exhibited the classic features of tachycardia, muscle rigidity, cyanosis and hyperthermia; the core temperature reached 42°C antemortem. To date, seven members of the family have subsequently been screened for susceptibility to MH by IVCT of biopsied skeletal muscle utilising the methods and diagnostic criteria of the European MH Group [5, 6].

In our laboratories, once the muscle is in the tension study apparatus and stimulated to contract utilising a pulse of 0.1 amp at 0.25 Hz, the muscle is left for 5 min to establish a regular baseline before individual muscle strips are subjected to challenge by halothane and caffeine. At the end of the procedure the challenging substances are removed and the muscle, still being stimulated, is allowed to return to baseline confirming the contractility and viability of the muscle strip.

Muscle of three members of the family (see Fig. 1) has satisfied the diagnostic criteria for susceptibility to MH. These results are in Table 1.

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Anaesthesia, 1992, Volume 47, pages 57–58

Forum

The 'whoosh' test

A clinical test to confirm correct needle placement in caudal epidural injections

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Summary

We describe a previously unreported test to confirm accurate needle placement in caudal epidurals. Of 26 patients undergoing caudal epidural, 19 (73%) had correct needle placement as determined by epidurography. All of these had a positive 'whoosh' test. There were no false positives.

Key words

Anaesthetic techniques, regional; caudal.

Epidural injections of local anaesthetic agents and corticosteroids are widely used to provide symptomatic relief in patients suffering from low back disorders. The caudal route, although theoretically safer in that the risk of dural puncture is small, has the disadvantage that needle placement is less certain. We describe a clinical test to confirm the position of the needle in the epidural space, and assess the accuracy of the method using epidurography on a series of patients.

Methods

Patients who were suffering from low back pain and sciatica were studied. Any patient having a contraindication to contrast media or radiological investigation was excluded from the study.

Blood pressure and pulse measurements were made with the patient supine; they were then placed in the prone position and, under aseptic conditions, the sacral hiatus was palpated and the skin infiltrated with local anaesthetic (lignocaine 1% 2 ml). A 21G needle was inserted through the sacrococcygeal membrane, and aspiration performed to ensure that the needle had not penetrated a blood vessel or the dura. The operator then applied a stethoscope over the thoracolumbar region in the midline and listened as a volume of approximately 2 ml of air was injected. Our hypothesis was that if the needle was truly in the epidural space; then a 'whoosh' heard with the stethoscope upon injection would confirm the passage of air proximally in the epidural space; a positive test. Conversely, a needle position that lay outside the epidural space would not produce such a sound; a negative test.

The position of the needle was confirmed by injecting 5 ml of contrast medium (Niopam 300) and taking plain X rays (AP and lateral) to detect the presence of contrast in the epidural space. If the position was confirmed, the therapeutic injection was performed; otherwise the needle was withdrawn and resited. Afterwards the patient was admitted to hospital overnight and routine observations performed.

Table 1. Correlation of 'whoosh' test to epidurogram.

	Epidurogram +ve	Epidurogram −ve
'Whoosh' test +ve; patients	19	0
'Whoosh' test −ve; patients	0	3
'Whoosh' test uncertain; patients	0	4

Results

A total of 26 patients were included in the study (Table 1). There were seven patients classified clinically as obese; six women (mean weight 81 kg) and one man (weight 117 kg). Of these patients, three had a positive test confirmed by epidurography. The other four patients had needle positions outside the sacral hiatus, confirming the difficulty of needle placement in obese patients. However, instead of a silent 'whoosh' test the operator heard a high pitched crackling sound with the stethoscope and was able to palpate air in the subcutaneous fat. This small series showed the 'whoosh' test to be both specific and sensitive.

Discussion

The caudal route of entry to the epidural space is preferred to the lumbar route by many practitioners, because accidental puncture of the dural sac, with the subsequent risk of intrathecal injection of medication, is rare. Dilke *et al.*

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reported a dural tap rate of 14% using the lumbar route [1]; White, reporting on a much larger series of over 2000 patients treated with caudal epidurals, describes only two cases of intrathecal injections [2]. Other complications ascribed to lumbar epidural injections include bacterial meningitis, adhesive arachnoiditis, aseptic meningitis, sclerosing spinal pachymeningitis [3], and in these conditions breaching the dura is the likely common factor. Because of these complications, the sacral route would appear safer and more applicable as a day-case or outpatient procedure.

However, even in the hands of a skilled practitioner up to 25% of the injections using the caudal route do not enter the epidural space [2]. For this reason, it has been advocated that needle placement should be confirmed by fluoroscopy alone [2] or epidurography [4], and successful entry into the epidural space has been reported in 97.5% using this latter technique [4]. The practical and logistical difficulties that this entails are not inconsiderable, and the complications of epidurography have been reported as similar to those of myelography [5], (although with the small volumes required to confirm needle position these complications are less likely). Hence the attraction of a simple clinical test to confirm the needle position.

The terms epidurogram and epidurography were first used to describe the injection of air into the epidural space to outline lumbar disc protrusions [6]. The volumes injected were large, 200 ml used routinely, and up to 600 ml used on occasion, all without adverse effects. Provided that air is not injected into a vessel or the thecal sac, the described procedure would appear to be entirely safe, particularly in view of the small volume of air necessary. It is simple to perform, takes very little time and has proved effective in confirming the needle position during caudal epidural injections.

Acknowledgment

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Epidural infusion of bupivacaine and diamorphine for postoperative analgesia

Use on general surgical wards

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Summary

An audit of postoperative epidural analgesia in a District General Hospital is presented. Three hundred and forty-eight patients received epidural infusions of a bupivacaine and diamorphine mixture, and were managed on general surgical wards using a standard protocol of observations and instructions. Good analgesia was achieved in 339 (97%) patients. Respiratory depression, defined as a respiratory rate of eight breaths.min^{-1} *or less, occurred in 22 (6%) patients, was of gradual onset, and was simply and successfully managed without morbidity. There were no respiratory arrests. Other complications, and the significance of catheter insertion level are discussed.*

Key words

Pain; postoperative.
Analgesics; diamorphine.
Anaesthetic techniques, regional; epidural.

A review in 1979 [1] emphasised the inadequacy of postoperative pain management and suggested that a radical new approach was necessary. The first report of epidural opioid administration for postoperative analgesia appeared in the same year [2], and since then the technique has been used extensively in a variety of settings. The benefits, mode of action and pharmacokinetics have been widely discussed [3–5].

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However, there have been many reports concerning the adverse effects of epidural opioid administration, and these have been reviewed in detail [6]. In particular, the problem of late and sudden respiratory depression has drawn attention to the level of surveillance required in patients receiving epidural opioids [7,8]. This complication has been most commonly reported following the use of epidural morphine, a poorly lipophilic agent, given by intermittent injection [9,10]. Drugs of greater lipophilicity, such as fentanyl and diamorphine, are considered to offer a greater degree of safety than morphine for epidural use [11]. Additionally, administration by infusion should produce side effects in a more gradual manner than administration by intermittent injection.

Continuous epidural delivery of a local anaesthetic and opioid mixture by infusion is an alternative approach which has been shown to provide superior analgesia compared with either drug given alone [12]. After careful consideration, our department decided to adopt an epidural infusion technique, using a mixture of diamorphine and bupivacaine, for use on general surgical wards. This report presents an audit of our first 2 years' experience.

Methods

Patient selection and intra-operative technique The technique was used in the management of both elective and emergency surgical patients undergoing intrathoracic, intra-abdominal, and lower limb surgery. Accepted contraindications to the insertion of an epidural catheter were observed [13], although concurrent administration of low dose heparin or intra-operative intravenous heparin following catheter insertion were not considered to preclude its use.

Epidural catheters were placed by anaesthetists of registrar grade or above, either under local analgesia before induction, or after induction of general anaesthesia. A sterile technique with a 16-gauge Tuohy needle was used. Most catheters were inserted at the interspace corresponding to the dermatomal level of the incision, although some clinicians used the lumbar space exclusively for all types of incision. Those using the midthoracic spaces normally adopted a paramedian approach, otherwise a standard midline approach was used.

No standard anaesthetic regimen was specified for intra-operative management. Intermittent doses of bupivacaine 0.25–0.5% were used and most patients also received a loading dose of epidural diamorphine which was determined by the anaesthetist. No systemic opioids were given, apart from a modest dose of short-acting opioid at induction, when clinically indicated. Hypotension was treated with fluid administration and/or ephedrine.

Postoperative management After the patient recovered consciousness in the recovery room, a standard syringe pump infusion of 0.166% bupivacaine with diamorphine was connected to the epidural catheter by the recovery nurse. The dose of diamorphine added to each 60 ml of 0.166% bupivacaine was 5 mg for patients aged 65 years or above, or 10 mg for those under 65 years (for small or debilitated patients 5 mg was used). All syringes were prepared by the hospital pharmacy and labelled for each specific patient. The rate of infusion was adjusted (1 to 6 ml.h^{-1}) until the patient was able to take a vital capacity breath with minimal discomfort. The infusion details were prescribed on a standard drug chart, and the protocol (Table 1), with instructions for patient observations and the emergency nursing management of complications, accompanied the patient to the general ward. A formal assessment of sedation was not made. The level of hypotension at which intervention was required was at the discretion of the anaesthetist; most used a systolic pressure of less than 95 mmHg in a patient who was normotensive preoperatively. There was 24-h availability of resident anaesthetic staff.

The ward nursing staff adjusted the rate of infusion according to their judgement of patient analgesia, and patients were encouraged to mobilise from the first postoperative day, if appropriate.

Before this epidural regimen was instituted, tutorials were held with the ward nursing staff (usually in groups of 7–10) at which both theoretical and practical aspects of management of epidural infusions, including complications, were discussed. Thereafter any problems were channelled through the Senior Sister or Charge Nurse on each ward who were seen frequently but informally. Further tutorials were held when considered appropriate.

Data collection Each patient was assessed by a single consultant anaesthetist (F.L.R.) on the first postoperative day and following catheter removal. Further assessements were undertaken if any problems occurred. Analgesia was assessed using a pain score (Table 2), and adverse effects and their management were recorded. These included respiratory depression (defined as a respiratory rate of 8 or less), hypotension, pruritus, urinary retention, unwanted lower limb motor blockade or numbness, nausea and vomiting, or dysphoria.

The mean loading dose of diamorphine given in the operating theatre was recorded, as was the subsequent dose of diamorphine given over the first postoperative 24 h. The median infusion rate over the same period was also noted.

Table 1. The protocol. Instructions to nursing staff regarding patients with continuous epidural infusions postoperatively.

Epidural administered by: ....
Home phone: ....Radiopage: ....

Observations

1. *Respiratory rate*: count and record every hour for 24 hours, then 4 hourly thereafter. If it falls to *8 or less per minute*, stop the epidural infusion and call the anaesthetic registrar on call. If it falls to a dangerously low level (4 or less per minute), in addition give naloxone 0.2 mg stat.
2. *Blood pressure*: measure and record every hour for 4 hours, every 2 hours for 4 hours, and every 4 hours thereafter. If the *systolic blood presure falls below   mmHg*, and surgical causes have been excluded, call the anaesthetic registrar on call, and stop the epidural infusion.

Precautions

1. Keep 1 ampoule (0.4 mg) of naloxone and a syringe and needle by the bedside at all times.
2. No other narcotic drugs or sedatives are to be given to the patient without consulting the anaesthetic registrar on call.
3. Should persistent itching be a problem, call the anaesthetic registrar.
4. If persistent nausea and vomiting occur despite prescribed anti-emetics, call the anaesthetic registrar.

Table 2. Pain score.

Score	Clinical correlate
0	No pain at rest or with movement*
1	No pain at rest/slight with movement
2	Moderate pain at rest/severe with movement
3	Severe pain at rest

* Asking the patient to take a maximal inspiration, sit up, and touch each side of the bed with the opposite hand.

Table 3. Patient data.

Sex	23 Male, 135 Female
Age; years, mean (range)	63 (14–91)
Weight; kg	67 (36–129)

Results

Demographic patient data are shown in Table 3. Table 4 gives the surgical incisions performed, levels of catheter insertion, and infusion details.

Analgesia A pain score of 0 or 1 was considered to represent good analgesia, whereas a score of 2 or 3 was considered to indicate inadequate analgesia. On the first postoperative day good analgesia was achieved in 339 (97%) patients, (225 with a score 0, 114 with score 1).

Details of the nine patients with inadequate analgesia are displayed in Table 5. Six of the nine patients had lumbar epidurals for thoracic incisions. Three of the patients were successfully managed by increasing the diamorphine content and/or the rate of infusion, and in one patient good analgesia was obtained by resiting the epidural catheter in the midthoracic region. In the other five patients, the catheter was removed and an alternative analgesic technique substituted.

Adverse effects Table 6 shows the incidence of adverse effects. There were no deaths related to the epidural infusions.

Respiratory depression occurred in 22 patients (6%). The time of its occurrence is shown in Figure 1; in all cases it was within 24 h of operation. The decline in respiratory rate was gradual in all patients, with no respiratory arrests, and a lowest recorded respiratory rate of 5 breaths min^{-1}. Eight of the patients with respiratory depression were noted to have documented chronic respiratory disease. Most patients were successfully managed simply by temporarily stopping the infusion (0.5 to 3.5 h) and subsequently reducing the administration rate of diamorphine. No patient received naloxone as an emergency measure, although in five patients naloxone was administered by the attending anaesthetist to hasten recovery.

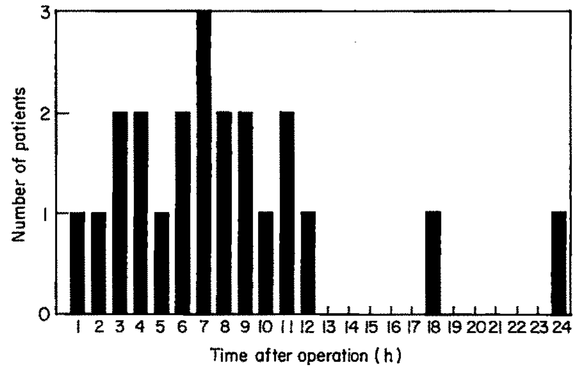

Fig. 1. Times of onset of respiratory depression.

Hypotension attributed to the epidural infusion occurred in nine patients (2.6%), and was corrected with fluid therapy and adjustments to the infusion rate in all but three patients. In these three patients the bupivacaine was removed from the infusion mixture, with maintenance of adequate analgesia by an increase in the administration rate of diamorphine.

Twenty-six patients (7.5%) experienced pruritus, of whom 19 required treatment. This was successful in 18 patients using intravenous naloxone (without reducing analgesia) and/or chlorpheniramine. In one patient, however, the pruritus was sufficiently intractable and severe to necessitate removal of the diamorphine from the infusion.

Unwanted lower limb blockade was observed in 12

Table 4. Types of incision, catheter level and infusion details.

Incision	No. of patients	Catheter level	No. of patients
Thoracic	97	Mid-thoracic T_{5-6}—T_{8-9}	95
Upper abdominal	98	Low-thoracic T_{9-10}—$T_{12}L_1$	171
Lower abdominal	143	Lumbar L_{1-2}—L_{4-5}	82
Lower limbs	10		
Totals	348		348

Infusion details	Mean	Range
Catheter duration; days	3.9	1.0–11
Infusion rate; ml.h^{-1}	3.5	0.5–10
Loading dose diamorphine; mg	2.0	0.0–10
Diamorphine; mg.24 h^{-1} (excluding loading dose)	9.5	1.0–40

Table 5. Patients with inadequate analgesia.

Age; years	Weight; kg	Incision	Catheter level	24 h diamorphine; mg	Treatment
68	65	Upper abdominal	Mid-thoracic	12	DM increased to 10 mg.60 ml^{-1}
76	69	Thoracic	Lumbar	12	DM increased to 10 mg.60 ml^{-1}
66	65	Thoracic	Lumbar	24	Rate increased to 10 ml.h^{-1}
75	65	Thoracic	Lumbar	16	Catheter removed
64	80	Thoracic	Lumbar	6	Catheter removed
66	53	Thoracic	Lumbar	9	Catheter removed
39	70	Thoracic	Lumbar	20	Catheter resited mid-thoracic
59	75	Thoracic	Low thoracic	24	Catheter removed
56	75	Thoracic	Low thoracic	24	Catheter removed

Table 6. Adverse effects.

	No. of patients	%
Respiratory depression	22	6.3
Inadequate analgesia	9	2.6
Hypotension (epidural)	9	2.6
Pruritus	26	7.5
Lower limb blockade	12	3.5
Urinary retention (out of 23 patients)	6	26.1
Persistent nausea and vomiting	4	1.1
Dysphoria	2	< 1.0
Dural tap	9	2.6
Accidental catheter occlusion or removal	7	2.0

patients (3.5%), all of whom had lumbar epidurals. In eight of these patients the catheter was removed at the patient's request, despite adequate analgesia.

The high incidence of urinary retention (six out of 23 noncatheterised patients) led to a decision to leave a urinary catheter in all patients for the duration of the epidural infusion.

None of the nine patients who had a dural tap (2.6%) complained of headache during the postoperative period or suffered any neurological sequelae.

Discussion

The rationale of using a mixture of local anaesthetic and opioid by epidural infusion is to produce effective analgesia whilst reducing the unwanted effects associated with the administration of each drug.

The incidence of good analgesia achieved in our patients (97%) compares favourably with those using postoperative epidural infusions of bupivacaine alone [14], intermittent morphine [15], and mixed infusions [16]. The mean loading dose of epidural diamorphine in our patients was 2.0 mg, and the mean dose of epidural diamorphine received in the first 24 h after operation was 9.5 mg. The latter dose is less than that used in a recent report using diamorphine alone by fixed-rate infusion or intermittent delivery [17], and similar to the dose given by a mixed infusion in another study [12]. The addition of bupivacaine to the infusion may allow the use of a lower dose of diamorphine, and since the risk of major side effects is related to the dose of opioid [18], it should contribute to the safety of the technique without reducing analgesic efficacy. There was a large individual variation in dose requirement, therefore the use of a fixed infusion rate, which may lead to a higher incidence of either inadequate analgesia or adverse effects, cannot be recommended.

The optimal level of epidural catheter insertion is the subject of controversy. Use of the lumbar level for high incisions can be effective [19,20], and some consider it to be a safer technique than insertion in the thoracic region [21]. Others conclude that siting the epidural catheter at a dermatomal level appropriate for the incision is superior [22]. However, when using a combination of local anaesthetics, opioids of high lipophilicity (which provide more segmental analgesia [6]) and an infusion technique (which produces less spread [5]), the use of the lumbar route in patients with high incisions may increase the likelihood of inadequate analgesia. The fact that six of our nine patients with inadequate analgesia had lumbar catheters for thoracic incisions supports this view. We therefore recommend placement of the epidural catheter at a level appropriate to the innervation of the surgical incision when using this infusion technique.

Both early and late respiratory depression have been reported following epidural diamorphine [23]. The incidence of respiratory depression (as defined above) in our patients was 6%, and its onset was gradual in all 22 patients, an observation previously reported [24]. An infusion technique may therefore either enable respiratory depression to be anticipated or reduce its severity at onset.

Several methods for monitoring respiration have been described [25]. In the clinical situation, hourly monitoring of respiratory rate is commonly used and may be the most discriminatory clinical indicator of respiratory depression [26]. However, as the relationship between respiratory rate, hypoxia, and hypercarbia is not wholly reliable [11], its use alone has been criticised [6]. In practice, this simple clinical observation may be the only feasible method available to those departments that wish to utilise epidural opioids widely in the management of postoperative pain, and we have demonstrated its effectiveness with this infusion technique. Regular assessment of the degree of sedation has been used to complement respiratory rate by some clinicians [27]. We considered that frequent arousal of patients from pain-free sleep in order to assess sedation would not be justified, since the other postoperative observations are possible without doing so. This apparently did not lead to problems in any of the 348 patients.

Of the factors recognised to predispose to respiratory depression in patients receiving epidural opioids [11], we noted the presence of chronic respiratory disease in eight of our 22 patients with respiratory depression. In this series, advanced age and thoracic epidural insertion did not appear to be risk factors. The presence of a dural breach has also been associated with respiratory depression [28], but there were no problems in our nine patients who had dural taps.

Respiratory depression did not occur after the first 24 h after operation in our patients, and in most it was observed during the first 12 h. This has obvious implications for the level of surveillance during the first 24 h after operation and hence the instructions in our protocol. These are similar to those of Ready *et al.* [27] and follow the guidelines given by Martin *et al.* [29]. There are now several reports of the successful and safe management of patients receiving epidural opioids on general wards [10,27,30–32].

Urinary retention, a well documented problem [33], is a complication of both epidural local anaesthetics and opioids, therefore it is not surprising that early in the trial the incidence in our patients without urinary catheters was high. We now insert urinary catheters in all patients who receive this technique.

The incidence of other side effects, in particular nausea and vomiting, hypotension, and pruritus, compares favourably with reports in the literature [5, 10]. These side effects were successfully and simply managed in the majority of patients. In some patients removal of one component of the infusion was an effective treatment of persistent side effects. The fact that this did not seriously compromise the quality of analgesia demonstrates the flexibility of the technique.

In conclusion, we consider that the use of a mixed infusion epidural technique is a highly effective method of providing postoperative analgesia after intrathoracic, intra-abdominal and major lower limb surgery in appropriately selected patients. In addition, the technique has an acceptably low incidence of side effects. We believe that the technique need not be restricted to intensive care or high dependency units provided that there is education of staff and a standard monitoring protocol is used. However, we advocate siting the epidural catheter at the same dermatomal level as the surgical incision, so that optimal analgesia is provided, whilst the dose of opioid used is kept to a minimum.

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Propofol and serum potassium

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Summary

The aim of this study was to examine the effect of propofol and propofol with suxamethonium on serum potassium concentration during induction of general anaesthesia. Forty patients were studied during elective surgery and serum electrolytes were measured before and after the induction of anaesthesia. Patients were allocated at random into two groups to receive either propofol alone or with suxamethonium. The serum potassium fell by 0.04 mmol.l^{-1} by 5 min after induction with propofol alone but had recovered to the pre-induction level by 10 min. The serum potassium rose by 0.23 mmol.l^{-1} when a combination of propofol and suxamethonium was used for the induction of anaesthesia.

Key words

Ions; potassium.
Anaesthetics, intravenous; propofol.
Neuromuscular relaxants; suxamethonium.

The use of propofol is established in both the induction and maintenance of general anaesthesia. It may be used alone or in combination with other agents which might have an effect on serum potassium concentration. Thiopentone and methohexitone decrease serum potassium when administered alone or attenuate the rise in serum potassium concentration when administered with suxamethonium. The aim of the present study was to examine the effect of propofol and propofol with suxamethonium on serum potassium concentration during induction of general anaesthesia.

Methods

Forty ASA 1 or 2 patients scheduled for elective surgery were allocated at random two groups, group P to receive propofol alone or group PS to receive propofol and suxamethonium. The protocol was approved by the local hospital ethics committee and informed consent was obtained from all the patients.

Patients were premedicated with temazepam 20 mg 2 h before operation. Routine monitoring included electrocardiogram, pulse oximetry, end-tidal carbon dioxide concentration and noninvasive blood pressure. Two 20 gauge cannulae were inserted into large antecubital veins in each arm. One was for the administration of drugs and the other for blood sampling. A pre-induction blood sample was withdrawn without venous occlusion for serum electrolyte estimation. Anaesthesia was induced in both groups with 2.5 mg.kg^{-1} propofol over 20 s and followed by suxamethonium 1.5 mg.kg^{-1} in the propofol and suxamethonium group.

At 1, 2, 3, 5 and 10 min after the injection of propofol, 5 ml of venous blood was obtained for serum potassium analysis. These samples were stored in heparinised bottles and transferred immediately to the laboratory for potassium analysis. Any samples showing signs of haemolysis were excluded from the study. All samples were analysed using a Corning '480' Flame Photometer; the precision of the analysis was 0.1 mol.l^{-1}. This apparatus had a with-in run coefficient of variation of 0.5% and a between-batch precision coefficient of variation of 1.7%. Patients received 100% oxygen for 3 min and then nitrous oxide and oxygen (66:33). At 5 min from induction 2% isoflurane was administered.

The lungs of apnoeic patients were ventilated if required, but their end expiratory carbon dioxide was kept between 5 and 6 kPa. Additional boluses of propofol (20 mg) were administered to any patient considered to be clinically light during the study period. The tracheas of patients in the suxamethonium group were intubated after the 1 min sample had been taken.

Results

The results of one patient in the propofol and two in the propofol and suxamethonium groups were not included because of haemolysed samples. There were thus 19 patients in the propofol and 18 in the propofol and suxamethonium group. The mean total dose of propofol over the 10 min study period in group P was 3.05 mg.kg^{-1} (including the 2.5 mg.kg^{-1} used for the initial induction). This was because of the use of extra boluses of propofol when the patient seemed light during the study period. There was a slight fall in serum potassium after induction of anaesthesia with propofol. The reduction in serum potassium was about 1%, falling to a minimum at about 5 min after induction and recovering to baseline pre-induction levels by 10 min. The results are summarised in Table 1.

Table 1. Group P (propofol alone).

Mean serum potassium mmol.l^{-1} (SEM) at times in min

Time; min	0	1	2	3	5	10
Potassium; mmol.l^{-1}	3.82 (0.04)	3.76 (0.03)	3.76 (0.03)	3.74 (0.04)	3.73 (0.03)	3.89 (0.06)

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Table 2. Group PS (propofol and suxamethonium).

Mean serum potassium mmol.l^{-1} (SEM) at times in min

Time; min	0	1	2	3	5	10
Potassium; mmol.l^{-1}	3.89 (0.9)	4.04 (0.1)	4.12 (0.1)	4.13 (0.09)	4.15 (0.11)	4.15 (0.09)

The mean total dose of propofol over the 10 min study period in group PS was 2.5 mg.kg^{-1}. In this group serum potassium rose by about 6% at about 2 min after induction and remained high throughout the study period. The results are summarised in Table 2. This rise was statistically significant ($p = 0.01$ Dunnett *t*-test).

Discussion

It has been well established that induction of anaesthesia may cause a change in serum electrolytes and that this can be influenced by drugs used at the time of induction, whether inhalation or intravenous. Altered cardiovascular and respiratory physiology may also influence the patient's biochemical status [1]. Bali and Dundee in 1974 [2] described changes in relation to several induction agents. Stovner and colleagues [3] found that the average decrease in serum potassium was about 1% when using thiopentone or diazepam as opposed to 2–3% with propanidid or halothane. They also found that the average rise with suxamethonium was 12.7% with halothane and only 5.3% with thiopentone. This emphasised the ability of thiopentone to attenuate the rise of serum potassium caused by suxamethonium, and would indicate that the serum potassium will decrease by about 1% from the pre-induction level after a normal propofol induction and will rise by about 6% after a propofol and suxamethonium induction. These changes are very similar to thiopentone.

Propofol, used in emergency anaesthesia especially when rapid awakening is desirable, has not been investigated before in a similar manner. The patients in the above studies may not have been investigated or assessed as fully as patients for elective surgery, and could therefore be more at risk if propofol exacerbated the rise in serum potassium caused by suxamethonium. The results of our present study show that propofol causes a slight fall in serum potassium of about 1% and a rise of 5.8% when used in combination with suxamethonium. This is consistent with that found with other induction agents.

It is reassuring that such small changes occur when propofol is used and that these changes are unlikely to be of clinical significance. However, many factors in the peri-induction phase of anaesthesia may alter the serum potassium concentration (including anxiety [4], beta-$_2$ adrenoceptor agonists [5], antagonist [6] and carbon dioxide concentrations [1]) including anaesthetic agents. It is therefore important that the effect of commonly used induction agents on serum potassium concentration be established. It is reassuring that the changes in serum potassium are very similar to those found during induction of anaesthesia with barbiturates.

Acknowledgments

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$\dot{V}O_2$ and $\dot{V}CO_2$ following tourniquet deflation

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Summary

We examined changes in O_2 uptake, CO_2 output, blood pressure and heart rate following tourniquet deflation in 23 patients undergoing orthopaedic surgery of the lower extremities. A pneumatic tourniquet was applied for periods ranging from 21 to 106 min (mean 51 min). Prerelease values of $\dot{V}O_2$ (O_2 uptake at each min) and $\dot{V}CO_2$ (CO_2 output at each min) were 201 (37) and 174 (38) (mean (SD)) $ml.min^{-1}$, respectively. Significantly, $\dot{V}O_2$ and $\dot{V}CO_2$ increased by 55% and 80%, respectively, at 2 min after tourniquet release and returned to prerelease values within 8 min. The blood pressure fell significantly and the heart rate rose significantly. The increases in CO_2 output and O_2 uptake were dependent on the length of tourniquet inflation time; $Y = 4.7 \times (\text{tourniquet time}) + 54$, $r = 0.88$, ($p < 0.001$) for CO_2, and $Y = 1.3 \times (\text{tourniquet time}) + 99$, $r = 0.52$, ($p < 0.05$) for O_2. The slope of the increase in CO_2 output as a function in inflation time was 3.6 times greater than that of O_2 uptake. In conclusion, CO_2 output and O_2 uptake increased transiently after tourniquet deflation and the extent of the increase in CO_2 output is more than threefold as compared with that in O_2 uptake.

Key words

Tournique; effects of deflation.
Carbon dioxide output.
Oxygen uptake.
Anaesthesia; spinal.

A pneumatic tourniquet is commonly used for plastic and orthopaedic surgery of the extremities since it provides a bloodless field. Consequent ischaemia leads to tissue anoxia, resulting in an accumulation of anaerobic metabolites, which are released in the systemic circulation when the tourniquet is deflated to re-establish the blood flow. Previous studies have shown an increase in lactate [1–3], $Paco_2$ [1,2,4], and end-tidal carbon dioxide [4,5], and a decrease in pH [1–4,6] after tourniquet deflation. Dickson *et al.* [5] recently found an increase in end-tidal CO_2 from 4.3 to 5.5 kPa following tourniquet deflation at the lower extremity.

To our knowledge, however, there has been no report on changes in O_2 uptake and CO_2 output following tourniquet deflation. The purpose of this study is to examine the time courses of O_2 uptake and CO_2 output following tourniquet deflation, and to determine the quantitative changes in O_2 uptake and CO_2 output in relation to tourniquet inflation time.

Methods

This study was approved by the institutional review committee. Twenty-three patients undergoing extremity surgery with no history or symptoms of cardiovascular disease were studied. The mean age of the patients was 37(12) years (mean (SD)) (range, 15–72 years). Each patient was informed about the nature of the investigation and consent was obtained. ECG, automated blood pressure, $\dot{V}CO_2$ (CO_2 output per min) and $\dot{V}O_2$ (O_2 uptake per min) were monitored in each patient. They were all given spinal anaesthesia, induced by 0.3% dibucaine. On the average, the analgesia extended between S_5 and T_9. The patients were awake and breathed room air. No sedatives or hypnotics were administered. An intravenous infusion of compound sodium lactate solution (50–100 $ml.h^{-1}$) was set up in one forearm. The tourniquet system used was a pneumatic cuff and gauge connected to an oxygen source. After the lower limb was elevated to facilitate the drainage of blood, an Esmarch's bandage was applied to the limb and a pneumatic tourniquet was placed around the proximal part of the thigh and inflated to a pressure of 450 mmHg. The limb was then lowered.

At the end of the operation the tourniquet was deflated. $\dot{V}O_2$ and $\dot{V}CO_2$ were measured using a metabolic monitor (Deltatrac, Datex, Finland) with a canopy in spontaneously breathing patients. This instrument consists of an infrared carbon dioxide analyser, a paramagnetic oxygen analyser, a 4 l mixing chamber and a CRT display. Gas exchange ratios ($\dot{V}CO_2/\dot{V}O_2$) were computed simultaneously. The capabilities and accuracy of this instrument have been validated elsewhere [7].

Data were expressed as mean (SD). A one-way analysis of variance and the least significant difference test were used for pairwise comparisons between the controls (prerelease values) and the post release values. Tourniquet inflation times were correlated with the changes in CO_2 output and O_2 uptake by linear regression analysis. A p value less than 0.05 was considered to be statistically significant.

Results

The duration of tourniquet application ranged from 21 to 106 min (mean 51 min, $n = 23$). Figure 1 shows the typical time course of $\dot{V}O_2$ and $\dot{V}CO_2$ before and after the release of

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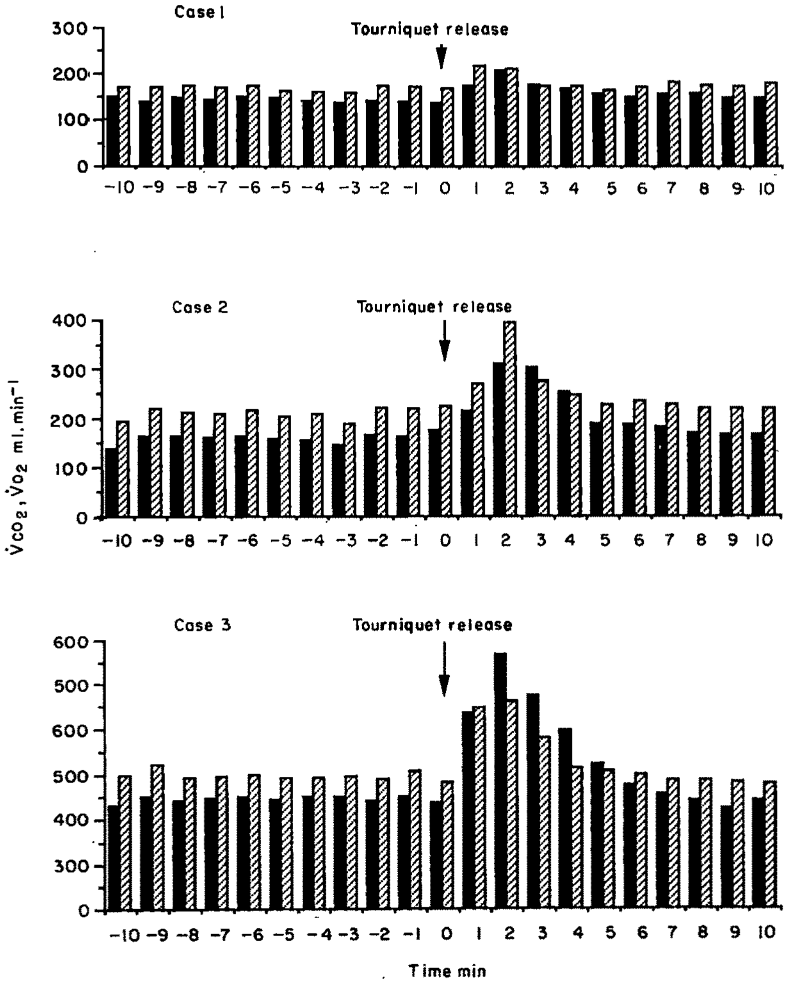

Fig. 1. Typical time courses of $\dot{V}co_2$ and $\dot{V}o_2$ associated with tourniquet release in three patients. Case 1 (*upper panel*); 51-year old; body surface area (BSA) 1.42 m^2, tourniquet inflation time 26 min. Case 2 (*middle panel*); 29-year old; BSA 1.63 m^2, tourniquet inflation time 51 min. Case 3 (*lower panel*); 27-year old; BSA 2.02 m^2, tourniquet inflation time 106 min. $\dot{V}o_2$ and $\dot{V}co_2$ increased transiently following tourniquet deflation. The increases were augmented as the tourniquet inflation time was prolonged. ■, $\dot{V}co_2$; ▨, $\dot{V}o_2$.

the tourniquet in three patients whose tourniquet time was 26, 51 and 106 min. $\dot{V}o_2$ and $\dot{V}co_2$ were fairly stable before the release, but immediately following the tourniquet deflation $\dot{V}o_2$ and $\dot{V}co_2$ rose, reaching maximum at about 2–3 min, and returned to prerelease levels within 8 min. It appeared that the longer the tourniquet was applied, the greater $\dot{V}o_2$ and $\dot{V}co_2$ increased following deflation.

Table 1 summarizes the mean values of systolic blood pressure, diastolic blood pressure, heart rate, $\dot{V}o_2$, $\dot{V}co_2$ and gas exchange ratio immediately before tourniquet deflation (prerelease); and 2, 4, and 8 min after deflation of the tourniquet in 23 patients. Systolic and diastolic blood pressure decreased significantly ($p < 0.05$) at 2 and 4 min, while the heart rate increased significantly ($p < 0.05$) at 2 min. $\dot{V}o_2$ increased by 55% at 2 min and returned to prerelease values within 8 min. $\dot{V}co_2$ increased 80% at 2 min, 40% at 4 min, and returned close to prerelease values at 8 min. Gas exchange ratio increased from 0.87 (0.10) to 0.99 (0.17) at 2 min and to 1.15 (0.21) at 4 min.

Increases in O_2 uptake and CO_2 output above resting

Table 1. Changes in heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), $\dot{V}o_2$, $\dot{V}co_2$ and gas exchange ratio at prerelease, and 2, 4, and 8 min after tourniquet deflation. Values are expressed as mean (SD); $n = 23$.

			After tourniquet deflation					
	Prelease		2 min		4 min		8 min	
HR (beat.min^{-1})	67	(12)	74	(8)*	65	(9)	64	(9)
SBP (mmHg)	122	(23)	108	(26)*	108	(27)*	114	(23)
DBP (mmHg)	67	(15)	55	(16)*	56	(15)*	60	(15)*
$\dot{V}o_2$ (ml.min^{-1})	201	(37)	312	(85)*	211	(44)	198	(39)
$\dot{V}co_2$ (ml.min^{-1})	174	(38)	314	(97)*	243	(68)*	181	(37)
Gas exchange ratio	0.87	(0.10)	0.99	(0.17)*	1.15	(0.21)*	0.92	(0.10)

*$p < 0.05$ vs prerelease.

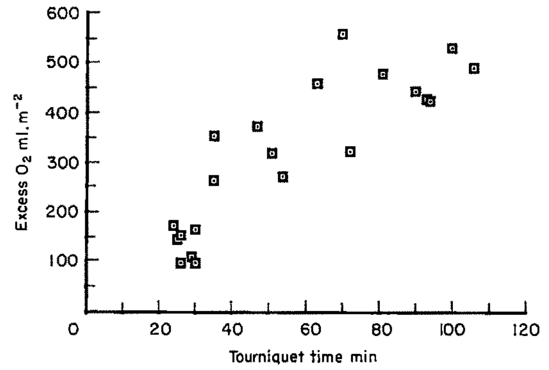

Fig. 2. Scatterpots of the relationships of excess CO_2 to tourniquet time. (Excess CO_2 (ml.m^{-2})) = 4.7 × (tourniquet time (min)) + 54, $n = 23$, $r = 0.88$, $p < 0.001$.

values, were defined as 'excess O_2' and 'excess CO_2'. Excess O_2 (CO_2) was calculated by integration of a difference of $\dot{V}O_2$ ($\dot{V}CO_2$) from a resting value (average of preceding 5 min) over 8 min after tourniquet deflation. Figure 2 shows the correlation between tourniquet inflation time and excess CO_2 (ml.m^{-2}). The results when fit to a straight line yielded the equation $Y = 4.7X + 54$ ($r = 0.88$, $p < 0.001$).

Figure 3 shows the correlation between tourniquet inflation time and excess O_2 (ml.m^{-2}). The results when fitted to a straight line yielded the equation $Y = 1.3X + 99$ ($r = 0.52$, $p < 0.05$). In comparison with excess CO_2, the correlation of excess O_2 was weak and it seemed to be unchanged when the tourniquet was applied for more than 50–60 min.

Figure 4 shows the correlation between tourniquet inflation time and maximal changes in systolic blood pressure, diastolic blood pressure, and heart rate. The data for those changes were obtained for 17 patients. There was no relation between tourniquet time and systolic and diastolic blood pressure, or heart rate.

Discussion

The major findings of this study were that O_2 uptake and CO_2 output increased transiently following tourniquet deflation as a function of tourniquet inflation time. CO_2 output increased more than O_2 uptake. Haemodynamic changes associated with tourniquet deflation were similar to previous studies [1,2,8], with an increase in the heart rate and a decrease in blood pressure.

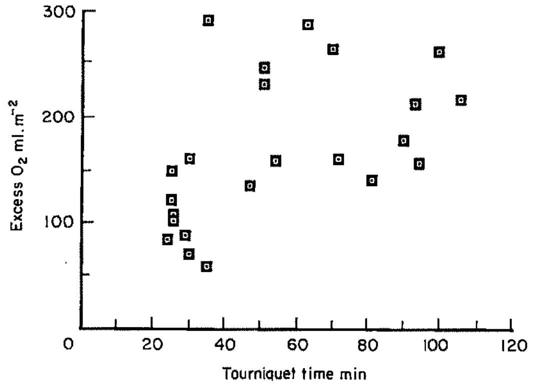

Fig. 3. Scatterpots of the relationships of excess O_2 to tourniquet time. (Excess O_2 (ml.m^{-2})) = 1.3 × (tourniquet time (min)) + 99, $n = 23$, $r = 0.52$, $p < 0.05$.

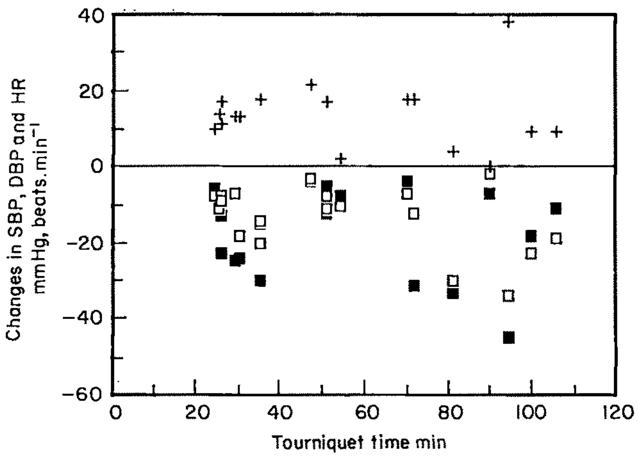

Fig. 4. Scatterpots showing the relationships between tourniquet time and maximal changes in systolic blood pressure (SBP, ■), diastolic blood pressure (DBP, □), and heart rate (+) Maximal changes in SBP, DBP, and heart rate (HR) showed a poor relationship to tourniquet time.

The increases in O_2 uptake and CO_2 output elicited following tourniquet deflation may have several possible causes. First O_2-depleted and CO_2-accumulated blood in the ischaemic extremity returns to the venous circulation immediately after tourniquet deflation, lowering the O_2 content and increasing the CO_2 content of mixed venous blood and later that of expired gas [9–12]. Wilgis [12] showed that the venous $P\text{O}_2$ and $P\text{CO}_2$ in the involved extremity changed after 90 min of tourniquet ischaemia with a pre-inflation of 6.0 and 5.1 kPa to 1.3 and 11.3 kPa, respectively. Solonen *et al.* [9] reported that the venous $P\text{CO}_2$ from the ischaemic limb increased to 11.3 kPa after 2 h of tourniquet ischaemia. During tourniquet inflation, although the tissue is exsanguinated, the O_2 is used by the aerobic metabolism until it is depleted. CO_2 is, on the other hand, produced by both aerobic and anaerobic processes. Under aerobic conditions, CO_2 production is associated with corresponding O_2 consumption, whereas under anaerobic states, CO_2 production continues even if the tissue is deprived of O_2. Lactic acid is the predominant anaerobic metabolite, which is buffered by HCO_3^-, releasing CO_2 [13]. This CO_2 production from the buffering of lactic acid occurs during ischaemia, and upon reperfusion of the extremity, the accumulated lactic acid is washed out into the general circulation and is buffered by plasma bicarbonate. Several studies [1–3,6,9,10,14] have shown an increase in lactate and a decrease in HCO_3^- of the vein and skeletal muscle in the ischaemic limb as well as in the systemic circulation. Second, an increase in minute ventilation which occurs upon release of the tourniquet, can decrease the functional residual capacity of the lung, and hence pulmonary nitrogen store can be diminished concomitantly with an increase in whole body oxygen stores [15], resulting in an increase in O_2 uptake. Similarly, an increase in minute ventilation can excrete more CO_2 than normal ventilation, resulting in augmentation of CO_2 output. These changes in O_2 uptake and CO_2 output can occur independently of any alteration of O_2 consumption and CO_2 production, and may be offset by restoration of ventilation to baseline values. Although we did not measure minute ventilation, the patients apparently maintained normal ventilation until 8 min after the release of tourniquet. It is unlikely therefore that changes in minute ventilation on measured $\dot{V}O_2$ and $\dot{V}CO_2$ contributed to the increases in $\dot{V}O_2$ and $\dot{V}CO_2$ after the release of tourniquet deflation.

Third, an increase in cardiac output, which has been reported to occur upon release of the tourniquet [4], can augment transport of venous blood from the tissues to the pulmonary circulation, resulting in an increase in O_2 uptake and CO_2 elimination from the lung, and hence a decrease in whole body O_2 and CO_2 stores. These changes in O_2 uptake and CO_2 elimination are also transient in nature, and may be offset by return of cardiac output to the baseline value.

Fourth, O_2 consumption and CO_2 production may increase following tourniquet deflation due to an augmented work load, such as an increase in minute ventilation and heart rate. It is also likely that oxygen debt in the previously ischaemic tissue may cause the increased oxygen extraction from the blood concomitantly with increased CO_2 production. Recovery of lactic acidosis, which is taking place over 30 min following tourniquet deflation [1], may produce a deficit of CO_2 stores, a decrease in CO_2 output. This change may affect in part the net excess CO_2 in the opposite direction.

The slope of excess CO_2 as a function of tourniquet inflation time was 3.6 times greater than that of excess O_2 (Figs 2 and 3), which indicated that the increase in CO_2 output was much greater than that in O_2 uptake. We showed that excess O_2 was related linearly to tourniquet time (Fig. 3), but, the linear relationship was weak ($0.01 < p < 0.05$). This seems to suggest that at more than 50–60 min of tourniquet inflation, the duration of ischaemia had little effect on excess O_2. If so, after a certain duration of tourniquet inflation time (more than 50–60 min), the ratio of excess CO_2 to excess O_2 would be greater than expected. The greater increase in CO_2 output than O_2 uptake suggests that CO_2 is produced in excess of O_2 consumption during and after tourniquet inflation. It is, however, impossible to quantify the anaerobically produced CO_2 from the difference between CO_2 output and O_2 uptake, since it is not confirmed in this study that body stores of O_2 and CO_2 have been restored to baseline during the measured period.

In conclusion, tourniquet deflation causes transient increases in O_2 uptake and CO_2 output proportionate to the duration of tourniquet inflation. These changes may be of clinical significance in patients with impaired cardiopulmonary function.

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And where *does* the time go during operating lists?

I have recently been examining variables and analysing results following a Waiting List Initiative in General Surgery. Surgeons vary greatly in the speed at which they work, even while producing very similar results; anaesthetists are wont to comment audibly on these ordinary 'nonpathological' variations. What is perhaps not examined so often is the equal, and also entirely human, variation between anaesthetists of equal excellence. In my post, indeed in the entire surgical department, the anaesthetic rota varies from week to week and is not usually publicised until the previous week, i.e. after patients have been sent for. Noting that my operating list-planning often turned out to be far from accurate, I decided to assess the extent to which anaesthetic time was a factor, since the anaesthetists almost always worked singly.

During several reasonably comparable lists of equal

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numbers of simple cases (herniae, haemorrhoids, unilateral varicose veins and the like), I kept a note of the 'operating time' (start of skin cleansing until final removal of sterile drapes for each patient) and the total list time. The percentage of the list consisting of 'nonoperating time' varied from 22% to 46%, the variation being principally and reproducibly the result of the particular anaesthetist allocated to that operating list.

I am most certainly *not* casting aspersions on any anaesthetists with whom I worked; all were first-rate, although their tolerance of my relatively slow and cautious operating varied! What I would like to point out is that, dull though it may be for anaesthetists, a regular allocation of the same anaesthetist to the same operating lists each week does make it easier to predict timing and therefore to plan operating lists more efficiently; the same benefit could derive from publication of a variable rota further in advance, before operating lists are planned and patients sent for. While I realise this may not be easy, especially at holiday times, even some attempt would probably save some cancellations of patients on the one hand or some wastage of precious operating theatre time on the other.

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Anticoagulant drugs and central nerve blockade

I was interested to read the excellent editorial by Drs Wildsmith and McClure on the subject of anticoagulant drugs and central nerve blockade (*Anaesthesia* 1991; **46:** 613–4). It contains extremely useful information and advice. However, similar problems may arise following the use of low molecular weight heparin. This recently introduced preparation of heparin has a more selective mode of action on the coagulation cascade. Its usefulness in perioperative thromboprophylaxis depends on selective inhibition of factor Xa and, unlike heparin, it does not accelerate the inhibition of thrombin. It also has a considerably reduced effect on platelet function and does not cause increased bleeding. However, it has high bioavailability and a longer half-life. Perhaps it is prudent to omit the preoperative dose of low molecular weight heparin and continue with it after the block has been instituted.

There is also the current concern about coagulation disorders and the complications which may arise from perioperative central venous ard arterial cannulation. Large cervical haematoma following venous cannulation in patients with a coagulation defect can cause severe respiratory obstruction [1]. Fatal haemothorax following an unsuccessful attempt to cannulate the right internal jugular vein has been reported [2].

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Detection of oesophageal intubation: can the 'cola complication' be potentially lethal?

In a letter to this journal Zbinden and Schüpfer [1] reported a high end-tidal CO_2 reading in a patient whose oesophagus had been accidentally intubated and who had ingested a carbonated beverage. They pointed out that heavy cola-consumption could delay the diagnosis of accidential oesophageal intubation. This was termed the 'cola complication'. In a hospital environment the capnographic display should easily reveal oesophageal intubation [2] and the 'cola complication' [3]. However, during emergency 'out-of-hospital' intubation, where capnography is not (yet) available, reliance has to be placed on semiquantitative or qualitative CO_2 detectors.

In order to assess the size of this cola complication, two available portable CO_2 detectors were used in an *in vitro* experiment. The MiniCAP III CO_2 Detector (MSA Catalyst Research, Owings Mills, Maryland 21117, USA) does not offer quantitative or semiquantitative capnometry; it reacts during each ventilation cycle to the presence of minute amounts of CO_2 ($>$ 0.3%) in the end-tidal gas with a beep and a flash. The disappearance or absence of CO_2 is signalled by an audiovisual alarm [4]. The FEF end-tidal CO_2 detector (FENEM, 84 William St, NY, NY 10038, USA) is a disposable device which semiquantitatively reacts during each ventilation cycle to the presence of CO_2 in the end-tidal gas with a change in colour, and a chart allows the rough assessment of the CO_2 concentration [5].

A heated (37°C) 2.3 l reservoir bag (representing the stomach) was filled with different contents and machine-ventilated (tidal volume 450 ml; frequency 20 min). The end-tidal CO_2 was monitored with the above described devices, as well as a capnometer.

With the reservoir bag filled with one can (333 ml) of cola, the MiniCAP signalled the presence of end-tidal CO_2 during 172 ventilation cycles (average value of 13 experiments (range 32–419); SD 133). With the reservoir bag filled with one can (333 ml) of Holstein Export beer, the MiniCAP signalled the presence of end-tidal CO_2 during 42 ventilation cycles (average value of five experiments (range 35–51); SD 6). When 40 ml bicarbonate 8.4% plus 50 ml HCl 1N were placed in the reservoir bag the MiniCAP signalled the presence of end-tidal CO_2 during 109 ventilation cycles (average value of six experiments (range 76–128); SD 20).

The MiniCAP is a very sensitive CO_2 detector; as such it can pick up trace amounts of CO_2 of any origin and 'fool' the observer. In the described setting it signalled, for a long time, the presence of 'end-tidal CO_2', leading to the incorrect assumption of a tracheal tube position.

The FEF monitor display was difficult to interpret, probably due to high humidity in the system; it failed to change colour on a breath-by-breath basis. The display initially turned yellow (high CO_2 levels) and only slowly changed to purple (no CO_2). Only the ambiguity of the display made it clear that something was wrong.

Surprised by the results implying that the cola complication could be potentially lethal, we repeated our experiments *in vivo*. In six anesthetised minipigs (used for other purposes) an additional tube was passed into the oesophagus and the stomach was filled with one can of cola. While bag-ventilating the lung, the mechanical ventilator was connected with the two devices in line to the stomach tube. Not once did the MiniCAP beep or the FEF change colour. Due to air trapping (lower oesophageal sphincter), there was no escape of CO_2 from the stomach.

When the stomach was ventilated well after the alarm sounded (MiniCAP), the barrier pressure was overcome and cola was regurgitated, inducing a beep (MiniCAP). Regurgitation while the FEF was used led to washout of the colour indicator and destruction of the device.

This demonstrates that the reservoir bag model of the stomach [1] as used is not appropriate, and thus the size of the cola complication cannot be inferred from its use in an experimental situation. We recommend the use of a portable CO_2 detector whenever an out-of-hospital intubation is performed. Nevertheless, as none of these 'tube position monitors' is fool-proof, they have to be used with caution and clinical judgement.

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Stereoisomers

The timely and very informative editorial on ropivacaine (*Anaesthesia* 1991; **46:** 339–40) is to be commended. However, I think the comments on terminology of stereoisomers are misleading. Dr Reynolds implies that S (sinister) and R (rectus) are the new names respectively for L (laevo) and D (dextro) always. Although this relationship often occurs, there is no necessary connection between the D, L and R, S conventions. For example, L-cysteine has the R-configuration. The D,L-nomenclature was based on assumed configurations of the two enantiomers of glyceraldehyde before it became possible to determine absolute configurations (1951). Except for the simplest molecules (containing an asymmetric carbon atom) this system is ambiguous.

The R,S-notation system [1] resolved this ambiguity and is preferable for specifying absolute configurations. It is systematic and uses one set of rules to correlate optically active compounds.

Incidentally, the chirality (right- or left-handedness) of configuration is no guide to the optical rotation of polarized light. Thus the R-configuration (or D for that matter) may rotate the plane of polarized light clockwise (dextrorotatory, +, d) or anticlockwise (laevorotatory, −, l).

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Reference

[1] Cahn RS, Ingold CK, Prelog V. The specification of asymmetric configuration in organic chemistry. *Experientia* 1956; **12:** 81–94.

A reply

I thank Dr McKenzie for his interest in my editorial. Without intending at the time to enter into any details of drug chirality, I merely wished to express regret that such a superfluity of classifications had become necessary even to describe a compound with a single asymmetric carbon atom. We already had L/D, l/d and +/−, the last two nomenclatures both describing the optical activity. Now, because in the past confusion has occurred, the configuration of the molecule *also* has an old and a new nomenclature, and neither is in English!

For compounds with more than one (let us say n) asymmetric carbon atoms there are of course 2^n possible stereoisomers, and then the situation can be forgiven for becoming complex.

The optical activity of the pipecholyl xylidine derivatives is of particular note because whereas the L or S form of mepivacaine is dextrorotatory (+) the S forms of propivacaine and bupivacaine are both laevorotatory (−). In all cases, however, the S forms are more effective as local anaesthetics.

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Desflurane in day case patients

Dr Wrigley and colleagues (*Anaesthesia* 1991; **46:** 615–22) have undertaken a detailed study of the new inhalational agent desflurane and its performance in comparison with propofol. Their results make interesting reading, but I have a number of reservations regarding their conclusions. The summary of this paper will be read by many clinicians who do not receive *Anaesthesia* and will also receive special attention from casual readers who scan only the summary and possibly the discussion. Although 'The overall quality of recovery was similar in all groups' and there were no significant between-group differences in recovery times, the authors highlighted (at length) certain nonsignificant trends and some modest differences in psychometric testing in the summary whilst omitting to mention a considerable number of potentially important adverse events. The number of patients in each group is not quoted in the paper and the groups are not described as being equal; nevertheless, I have assumed that there were in fact 15 in each group.

The quality of inhalational induction is admitted to have been variable and three of 30 patients (10%) did not tolerate it: of those who did 16 (59%) coughed, eight (30%)

Table 1.

	Desflurane (groups 1, 3 and 4)	No desflurane (group 2)
n	*42	15
Nausea	16 (38%)	1
Vomiting	6 (14%)	0
Sore throat	13 (31%)	1
Headache	9 (21%)	1

*Three patients in whom desflurane induction was abandoned are not included in this analysis.

held their breath and one vomited. These events were associated with marked increases in heart rate and blood pressure whereas propofol induction was haemodynamically stable. Potentially serious bradycardia (requiring atropine) occurred in seven of 42 patients (17%) who received desflurane and nine (21%) developed the less worrying nodal rhythm. Fentanyl and suxamethonium do indeed cause bradycardia but all patients received these drugs and it is therefore unreasonable to attribute the between-group differences to them. These events do not square up with the comment (Discussion) that 'desflurane has been shown to provide ... anaesthesia with no serious side effects'. The discussion also contains an unfortunate juxtaposition of sentences where a justification of the propofol infusion regimen of group 2 ('The propofol infusion regimen used in this study ...') is immediately followed by comments on bradycardia ('Seven patients had an episode of bradycardia ...'). The reader could be forgiven for thinking that the bradycardias were caused by propofol whereas they in fact occurred during maintenance of anaesthesia with desflurane (groups 1, 3 and 4). If it is considered appropriate to discuss trends which do not reach statistical significance then it is instructive to consider the between-group differences in nausea, vomiting, sore throat and headache (Table 1). All patients in group 2 received nitrous oxide and it is therefore inappropriate to attribute these events to that agent.

The authors chose to quote White's maxim that 'the ability to deliver a safe, effective general anaesthetic with minimal side effects and achieve a rapid recovery is critically important in the outpatient setting'; by these criteria their data suggest to me that desflurane may be unsuitable for day case anaesthesia.

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A reply

Thank you for giving us the opportunity to reply to the letter of Dr Sneyd.

It was our aim in reporting the results of this study to give a full account of our findings so that readers should be able to draw their own conclusions [1]. We do not agree with Dr Sneyd that the conclusions of our summary are misleading. Indeed we believe that it is misleading to state that we highlighted 'some modest differences in psychomotor testing'. The digit symbol modalities test at 30 min after operation in the propofol group was 50% worse than the three desflurane groups (change from baseline: propofol group −22; desflurane group −14), giving a significance level of $p < 0.05$. The 'p' deletion test, with respect to lines completed, at 30 min after operation in the propofol group was almost 100% worse than the three desflurane groups (change from baseline: propofol group −11; desflurane groups −6) giving a significance level of $p < 0.01$. We found that patients given desflurane made a significantly faster recovery than those given propofol for anaesthetic maintenance. Other workers have also found that in comparison with isoflurane, patients given desflurane made a significantly faster recovery [2, 3]; which is important in the outpatient setting. The number of patients in each group is clearly stated in Table 4.

In keeping with other workers [4] we found a high incidence of airway problems during inhalational induction of anaesthesia with desflurane. We would not normally advocate this method of induction in fit, young, unpremedicated adults. We would agree that an intravenous induction is usually smoother and also masks the changes associated with different stages of anaesthetic depth, including the excitement phase with its associated increases in heart rate and systemic arterial blood pressure.

We would agree that casual reading of the discussion concerning the groups in which bradycardia occurred might cause some confusion, however the findings were clearly stated in the results section.

With reference to the minor, self-limiting postoperative morbidity of nausea, vomiting, sore throat and headache, we did not attribute all those events to the use of nitrous oxide. We stated that nitrous oxide has an emetic effect [5] and propofol an anti-emetic effect [6, 7], which may explain the difference between the groups with regard to nausea and vomiting only.

We would reiterate White's maxim that 'the ability to deliver a safe, effective general anaesthetic with minimal side effects and achieve a rapid recovery is critically important in the outpatient setting'. We should also like to quote the conclusion of White and colleagues 'that desflurane may offer clinical advantages over isoflurane when administered for maintenance of anaesthesia in situations where rapid emergence and recovery of cognitive function are important' [2].

Time will tell whether the conclusions that Dr Sneyd has chosen to draw from the findings of our study ('desflurane may be unsuitable for day case anaesthesia') is appropriate; in agreement with White and colleagues we believe that desflurane may offer advantages over existing agents.

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Secondary transfer of patients

There has been recent interest in the standards of monitoring and care provided during the secondary transfer of patients in the United Kingdom [1–3]. This has coincided with the appearance of medical helicopter transfer systems [4, 5]. Although helicopters possess the advantage of speed, the most important aspect for most critically ill patients remains the *quality* of the transfer. This relates to the experience, grade and specialty of the transferring doctor, the available equipment and drugs, and the mode of transport.

Vyvyan *et al.* (*Anaesthesia* 1991; **46:** 728–31) comment that, during the secondary transfer of head-injured patients in the south of England, '... the quality of medical escort was poor, and the standard of monitoring equipment available was unacceptable ...' In particular they report that only 22.6% of hospitals possessed equipment which could measure intra-arterial blood pressure during transfer; they also confirm that noninvasive methods of monitoring blood pressure may be unreliable in transit [6]. Furthermore, they believe that the standards for monitoring head-injured, and, presumably, other critically ill patients, during transfer '... should be more intense ...' than those recently recommended for the anaesthetised patient by the Association of Anaesthetists [7]. These include a pulse oximeter, electrocardiograph, capnograph, and facilities for invasive and noninvasive pressure monitoring. Finally, they state that medical staff who escort head-injured patients (and, again, presumably other critically ill patients) must have appropriate skills.

Therefore, it may surprise some that the recently published minimum standards for helicopter transfer of patients [8], produced by a panel of which one of Vyvyan's co-authors is chairman, do not insist on the use of a capnograph, nor do they stipulate that *invasive* pressure monitoring is essential (merely insisting on 'blood pressure measurement'). Consequently, as with 96.8% of the hospitals in the study by Vyvyan *et al.*, helicopters equipped to these minimum standards possess insufficient monitoring.

Earlier this year, after the publication of the standards for medical helicopter systems, our Intensive Therapy Unit (ITU) needed to transfer urgently a patient to a national transplant centre. The patient, a young woman with a presumptive diagnosis of peripartum cardiomyopathy, was receiving intermittent positive pressure ventilation, and infusions of dobutamine, dopamine and noradrenaline. She was being monitored via an ECG, pulse oximeter, central venous line, pulmonary artery catheter and a femoral artery line; her pulse rate was in excess of $220.\text{min}^{-1}$, her arterial blood pressure was 100/70 mmHg, and she had severe pulmonary hypertension. One of us discussed, in detail, the patient's condition and the required level of monitoring with the duty flight registrar of a helicopter transfer system. When the helicopter team arrived at our ITU, it was apparent that invasive monitoring could not be undertaken because of the lack of appropriate equipment. Arterial blood pressure recordings could only be obtained via a noninvasive system, and venous and pulmonary artery pressures could not be measured. Furthermore, the same duty flight registrar who had accepted the call was quite prepared to transfer the patient *without* the appropriate invasive monitoring.

Having been delayed by several hours, the transfer was eventually undertaken by a consultant in Intensive Care via standard road ambulance with a police escort, using a modification of the equipment described by Park *et al* [9]. It is in fact recommended that the medical director of a helicopter transfer system should supervise audit of the scheme [8].

We are not opposed to the use of helicopter transfer systems, if appropriate. Neither do we suggest that there should be complacency over the current standards for the secondary transfer of critically ill patients. However, whichever mode of transport is chosen, it is important that proper standards of care and monitoring are maintained and we would urge all hospitals to consider the upgrade of their transfer equipment. If consideration is given to the transfer of a patient via helicopter, we recommend that it is done in the knowledge that the craft carries appropriate staff and equipment, rather than because it may be fashionable and/or exciting.

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A reply

We are grateful for the opportunity to reply to the letter of Dr Smith and his colleagues.

The points that they raise relate to the difference between primary transfers (moving a patient from the scene of injury to hospital) and secondary transfers (moving a patient between hospitals). The minimum standards publication [1] covered both primary and secondary schemes. It was not felt appropriate to insist on invasive monitoring or capnography for primary transfers, but this is not incompatible with our recommendation for capnography to be mandatory for secondary transfers of head injured patients. It would be quite improper for us to comment upon a specific transfer that was totally unconnected with our hospital. Nevertheless, since Careflight is the only secondary helicopter project in the UK, we conclude that Dr Smith and his colleagues must have requested the services of a primary system. This is equivalent to using an accident and emergency department for an intensive care patient. It is not the first such report that we have received.

We are deeply concerned that helicopter operators are attempting to set up medical helicopter systems with inadequate input from the medical profession. The resultant schemes, frequently under pressure to fly as much as possible to justify their costs, may attempt to undertake secondary transfers with staff and equipment designed for a totally different purpose, and, as witnessed by Dr Smith, fall short of the standards we have tried to set for secondary transfers.

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Reference

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Regional anaesthesia in pemphigus vulgaris

Pemphigus comprises a group of mucocutaneous diseases characterized by bullous eruptions of the skin and mucous membranes and is probably of autoimmune aetiology [1]. Pemphigus vulgaris is the most common form of pemphigus. It is characterized by impaired cell adhesion within the epidermis leading to the formation of intraepidermal blisters [1]. Whereas there is extensive literature on the anaesthetic management of epidermolysis bullosa, there are few reports of anaesthesia in pemphigus [2–5].

A 46-year-old white female with abnormal uterine bleeding, was admitted for abdominal hysterectomy and bilateral salpingo-oophorectomy. Eight years previously she had been diagnosed as suffering from pemphigus vulgaris. There was no associated internal malignancy. She was receiving prednisone 10 mg and azathioprine 100 mg daily. Physical examination revealed painful bullous formations in the mouth and oropharynx. Except for an iron deficiency anaemia, laboratory tests, chest X ray and electrocardiogram were within normal limits. Immunofluorescence showed IgG and C3 at the epidermal junction. Hydrocortisone (100 mg intravenously) was given pre-operatively and during surgery.

A continuous catheter spinal anaesthesia was the anaesthetic technique selected. A 25-gauge spinal needle was inserted easily at the L_{2-3} interspace and a 32 gauge microspinal catheter passed. The initial injection of 3 ml of plain bupivacaine 0.5% resulted in a T_7 level of sensory blockade bilaterally. No additional doses were necessary. At the same time, an epidural catheter was inserted at the L_{3-4} interspace. The intra-operative surgical and anaesthetic courses were uneventful. At the end of the operation the spinal catheter was removed. There were no lesions at the site of spinal needle puncture, blood pressure cuff, intravenous cannulation, or oxygen mask application (the face had been pretreated with vaseline gel). There were no lesions at any of the pressure points that had been in contact with the operating room table. In the recovery room and in the gynaecology ward 10 ml of plain bupivacaine 0.125% and 1 mg of morphine were administrated for pain control. The patient was discharged from the hospital on the 6th postoperative day.

The lesions of both pemphigus and pemphigoid resemble those of epidermolysis bullosa, and the anaesthetic management is probably the same, airway management being the primary concern [1]. Continuous thoracic epidural anaesthesia supplemented with intravenous ketamine has been used for cholecystectomy in a patient with buccal pemphigus [2]; a slow intravenous infusion of ketamine and epidural anaesthesia has been used for the removal of a rectal tumour [3]; continuous spinal anaesthesia has been used in undergoing radical vulvectomy [6].

This case illustrates how useful regional anaesthesia can be in providing satisfactory anaesthesia and postoperative pain control.

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Major incident plans

As part of our departmental audit we have recently carried out a survey of junior staff awareness of the local major incident plan (MIP) and of their degree of training in disaster medicine. This survey is particularly pertinent as the Association of Anaesthetists in their most recent report have discussed this issue and made recommendations for training [1].

Our survey included junior anaesthetic, surgical, medical and Accident and Emergency (A & E) staff of SHO level and above (32 in total). Only 69% of junior staff were aware that the Health District did have a MIP, but only 19% had ever seen a copy of the plan, or the section relevant to their specific role within it. No junior staff had been circulated with any literature relating to the MIP. The superficial high level of awareness of the MIP was related to a conspicuous poster campaign within the A & E department. Only 34% of junior staff had ever received any training period to familiarise them with major incident planning and of these only the A & E officers had received some training in this Health District. Our survey also revealed that 31% of junior staff had been involved in either real or simulated major incident alerts. Of these, half were involved with simulated alerts, but the majority of these were carried out whilst working abroad.

Only 6% of staff had been involved in MIP training exercises in this country. Although costly, annual full scale exercises involving both hospital and emergency services are recommended in the Association's report as essential for training. We also questioned the staff about their level of training in disaster medicine; 28% of staff felt they had adequate training in this field. On further questioning, however, only 13% appeared to have had appropriate training as defined in the Association's report, such as participation in Advanced Trauma Life Support courses or attendance at disaster medicine symposia.

Although only based on a small sample, this survey highlights a worrying lack of readiness for major incident management by junior staff. We intend to clarify the situation by extending the study to include all hospitals with major incident plans in the South East Thames Region and to include in our survey relevant consultant staff.

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Tracheal intubation: a complication

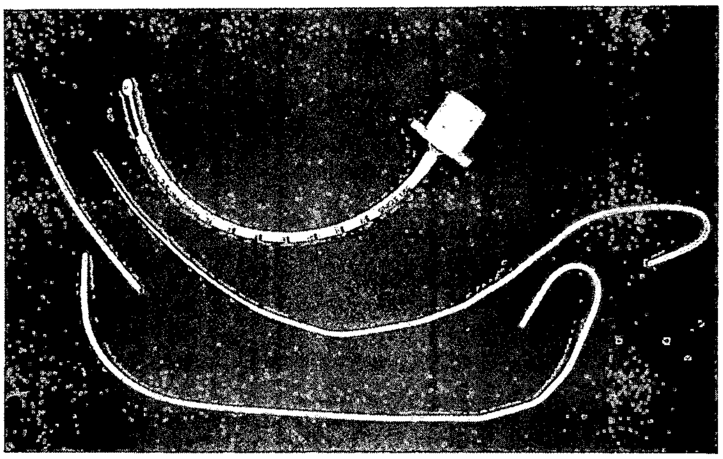

Fig. 1.

A 24-year-old woman underwent emergency lower segment Caesarean section at 28 weeks gestation for moderately severe pre-eclamptic toxaemia. Anticipating a small neonate which would require prolonged ventilatory support, a 2.5 mm internal diameter uncuffed oral tracheal tube (Portex, UK) was prepared by cutting it to an appropriate length. To facilitate intubation, a new unlubricated 2.2 mm external diameter tracheal intubation stylet (Portex, UK) was inserted into the cut tracheal tube. A 0.68 kg baby was delivered. Following initial resuscitation the trachea of the neonate was intubated with the prepared tracheal tube and stylet. The stylet was withdrawn with more than usual difficulty, and on inspection it was immediately apparent that damage had occurred to the stylet as bare wire protruded from the distal 5 cm. The tracheal tube was removed before the application of positive pressure ventilation, the larynx visualised, and the trachea re-intubated with a new tracheal tube.

Examination of the tracheal tube revealed a 9 cm length of plastic sleeve contained within its lumen, which readily fell out on straightening the tracheal tube (Fig. 1). On close inspection of the damaged stylet, the plastic sheath was found to have fractured over the wire core. It is unclear how this damage occurred in a new intubation stylet. The most likely explanation is indentation and fracture of an already weakened plastic stylet sheath against the tracheal tube connector on removal of the intubation stylet.

Introduction of foreign bodies into the bronchial tree is potentially fatal. This patient was fortunate that the foreign body in question was relatively large, rapidly recognised and removed before positive pressure ventilation instituted.

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A reply

The Portex Paediatric Intubation Stylet has been manufactured by Portex Ltd (Hythe, UK) for 9 years. It has been successfully used clinically in numerous healthcare markets worldwide. Investigation into the history of this product showed that the product has not changed for the last 9 years and that no previous incidents of this nature had been reported.

Upon notification of this incident, the users were visited and the stylet and tracheal tube taken for investigation in accordance with our Standard Operating Procedures. Inspection and testing of the product at Portex Ltd showed the stylet to be dimensionally within our specifications. The materials of construction were shown to comply with our normal standards and no structural defects could be detected. There was no evidence of any external factors such as mechanical damage which could have acted to produce this phenomenon. Close examination of the area of the fracture revealed that stretching and necking (narrowing) of the sheath material had taken place to such an extent that it passed the Yield Point and snapped. Yield Point is reached when sufficient force is applied to produce necking.

The same product was submitted for independant examination by an external consultant. The results were consistent with the in-house findings. There were no material or cosmetic deviations from the Portex Ltd specifications for this product. Comprehensive examination revealed no defects in the product which could have led to premature fracture of the sheath. As a result of these findings, we have concluded that the stylet sheath was stretched past its Yield Point in use, which resulted in its fracture, the yield point only being reached by application of considerable force.

We would like to re-emphasise that if difficulty is encountered during removal of any sheathed stylet from a tracheal tube, continuation of withdrawal of the stylet might lead to separation of the stylet sheath from the core. The stylet and tracheal tube should be withdrawn together and the intubation procedure repeated with a new stylet and tracheal tube if any incidence of difficult stylet removal is encountered.

We would like to thank the authors, and this publication, for the opportunity to reply.

Marketing Manager
Portex Ltd,
Hythe, Kent CT21 6JL

T. MARTIN

Laryngeal mask airway for elective tracheostomy

During 3 weeks working as the anaesthetist on board the 'Mercy Mission Ship, Anastasis' docked in a Ghanaian port, I anaesthetised two patients with ameloblastoma (giant West African jaw tumour) for mandibulectomy and partial reconstruction. In both cases an initial elective tracheostomy under general anaesthesia was proposed, the language barrier making a local technique difficult. The first patient was a 25-year-old female who was fit apart from a large mandibular tumour filling the floor of her mouth and pushing her tongue upwards and backwards. After premedication with diazepam 10 mg, an inhalational induction with halothane in oxygen was performed. The larynx could not be visualised by direct laryngoscopy. Fibreoptic equipment was unavailable, and as the anaesthetist did not consider himself adept at atraumatic blind nasal intubation, a size 3 laryngeal mask airway (LMA) was passed with ease.

As the correct position of the LMA is supraglottic, it did not need to be moved before insertion of the tracheostomy tube; the anaesthetic tubing was easily disconnected and reattached via a sterile catheter mount. The LMA was removed after the procedure had been completed. For the second patient, in spite of a visible larynx, the laryngeal mask was used in preference to a tracheal tube, as less anaesthetic manipulation was required, which was especially useful in the very cramped confines of a converted ship's cabin operating room.

Another example perhaps of using one's 'Brain'.

Heatherwood Hospital,
Ascot, Berks SL5

K.D. THOMSON

A problem with a laryngeal mask airway

We wish to report a case in which a Brain Laryngeal Mask Airway separated into two pieces upon its removal from a patient. The size 3 LMA had been inserted without difficulty in a 29-year-old male to provide a secure airway during routine varicose vein surgery. The patient was not observed to be biting on the LMA at any time during the procedure, and no tooth marks were discovered on subsequent inspection of the LMA.

The LMA was removed without excessive force, when it was noticed that the tube had sheared into two separate pieces, (Fig. 1) the smaller of which had remained in the pharynx. The patient was sufficiently recovered to obey commands and the remainder of the LMA was retrieved using the pilot tube which remained intact and connected to the cuff. A further sheared area was then discovered on the tube, but this had not separated. The LMA had been in use for less than 2 months, and had always been cleansed in accordance with the manufacturer's instructions. We have found it impossible to mark the LMA indellibly to denote the number of autoclave cycles which it has undergone. No abnormality had been detected during pre-insertion inspection of the LMA.

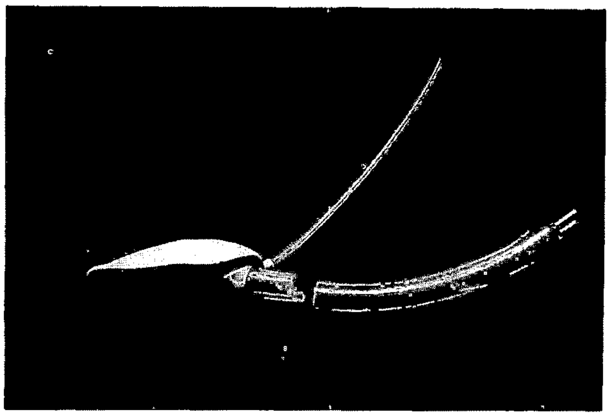

Fig. 1.

Our patient came to no harm as a result of this, but in other circumstances, a critical incident could have occurred.

Hairmyres Hospital,
East Kilbride,
Glasgow G75 8RG

M. CRAWFORD
G. DAVIDSON

A reply

The incident reported by Dr Crawford and Dr Davidson was brought to our attention on the 11 April 1991. The LMA in question was returned to our manufacturers for analysis. Their reply was summarised as follows: 'The brittleness/cracking is typical of the degradative effects on hard silicone rubbers arising from severe heat ageing'. There is no process during manufacture where this would occur.

We appreciate that all efforts were made by the hospital to clean and maintain the mask correctly and cannot therefore say for certain what happened to affect this particular LMA. The hospital has since been visited by a member of Colgate Medical Ltd to offer advice where necessary on care of the LMA and recommended pre-usage checks. It is strongly felt that this is vital. Careful inspection by anaesthetic assistants prior to use should detect most problems.

This is the only reported incidence of its kind in the UK in an estimated 200000 uses of the LMA. Intavent International S.A. have had no such similar occurrence in world-wide usage. However, this does highlight that we can never be too vigilant and are therefore grateful to the doctors at Hairmyres Hospital for bringing this to our attention.

Intavent Ltd,
Reading, Berks

K. WOODS

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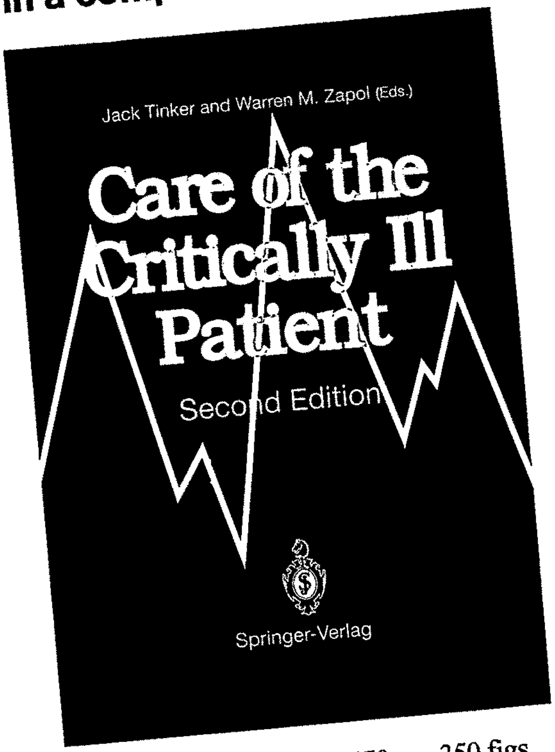
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Bacteraemia and insertion of laryngeal mask airways

Manipulations within the oral cavity can produce a transient bacteraemia [1], which has significance as a risk factor in infective endocarditis. Transient bacteraemia following nasotracheal intubation has been reported to be 16% in 25 patients [2], whilst another study found that the incidence following tracheal intubation was 2% [3]. The Brain laryngeal mask airway (LMA) is the latest addition to the anaesthetist's armamentarium for maintenance of an airway, and is introduced by a blind procedure that may produce unrecognised mucosal trauma. The LMA is not presented as a sterile package and whilst in position possibly lies in contact with a greater surface area, with a varied and more dense bacterial flora than would a tracheal tube.

We carried out a randomised, prospective study comparing the incidence of bacteraemic episodes in three groups of patients who required maintenance of an airway by means of oral or nasal tracheal tubes, or the LMA. Sixty patients were studied (15 orotracheal, 15 nasotracheal, 30 LMA) The groups were standardised for age, sex and ASA grading. Subjects were routine hospital inpatients scheduled for elective procedures, with no evidence of existing infection or structural heart disease and who had not received any antibiotic therapy for 2 weeks before surgery admission or whilst in hospital. Portex disposable tracheal tubes were used. The red rubber nasal tubes and the LMAs were not in sterile packs but were autoclaved and kept in clean storage.

Five ml of venous blood were collected immediately before induction and at 1, 3 and 7 min after instrumentation. A quantitative method was used to determine bacteraemia. The 5 ml of venous blood was diluted in 15 ml of molten agar and allowed to solidify in each of two sterile petri dishes. Both plates were incubated at 37°C, one in an atmosphere of air with 5% CO_2, the second in an anaerobic atmosphere. Plates were examined daily for growth, and colonies counted and subcultured for identification by standard methods [4]. Further identification of isolates was performed with API Staph and API Coryne (bio Merieux UK Ltd).

Seven patients had a bacteraemia. Six grew either *Staphlococcus epidermidis* or *Micrococcus* species. Four followed nasotracheal intubation and two introduction of LMAs. These represent contamination with skin flora, rather than a true bacteraemia following oropharyngeal manipulation. The level of bacteraemia was between 0.2 and 1.0 organisms per ml of blood. One patient had a bacteraemia with *Corynebacterium hofmannii* at 1, 3 and 7 min following tracheal intubation. Levels of bacteraemia were 1.4 organisms per ml blood at 1 min and 0.6 organisms per ml blood at 7 min.

Our results show that in healthy patients the risk of inducing a significant bacteraemia with an anaesthetic manipulation is virtually nil. However, for patients potentially immunocompromised, an anaesthetic procedure *per se* can induce a significant and prolonged bacteraemia. The significant bacteraemic episode occurred in a patient with widespread carcinoma who possibly had an unrecognised pre-operative infection, which was exacerbated following intubation. It is important to know not only the incidence of bacteraemia, but also the identity of the organism involved and the duration of the bacteraemia. The incidence of bacteraemia is no more with a LMA than with either oral or nasal intubation.

Queen Elizabeth Military Hospital,
Woolwich SE18 4QH

J.M. Stone
L.D. Karalliedde
M.L. Carter
N.S. Cumerland

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Identical twins too

Having just read the September issue of *Anaesthesia* and the letter on identical twins (*Anaesthesia* 1991; **46:** 800), imagine my delight at being presented with identical twin boys to anaesthetise the following day. The boys, aged 3 years, had an interesting past surgical history in that on the same day in 1988 they had cleft lip repairs and similarly in 1990 cleft palate repairs. Sadly the second operations were not successful and both patients now required further surgery on palatal fistulae. I, too, decided to alter my technique as a small clinical trial.

The boys weighed 12.8 kg and 13.2 kg respectively and were otherwise well. Neither was premedicated apart from the application of EMLA cream 90 min before operation. Anaesthesia was induced and maintained in twin 1 by computer-controlled propofol infusion, tracheal intubation facilitated by suxamethonium and breathing spontaneously a mixture of oxygen and nitrous oxide. A 12.5 mg diclofenac suppository was inserted at the time of induction. Anaesthesia in twin 2 was induced with thiopentone and maintained by the patient breathing isoflurane in an oxygen, nitrous oxide mixture, again following tracheal tube insertion with suxamethonium. An intramuscular injection of codeine phosphate (1 mg.kg) was given at induction.

The operations were similar in length and performed by the same surgeon who infiltrated the operating sites with 0.25% bupivicaine and adrenaline. At the end of the procedure 100% oxygen was administered to both twins and their tracheas were extubated when they were fully awake. For the next 24 h the nursing staff kept excellent clinical records of the patients' vital signs, including oxygen saturation, and allocated an hourly pain and sedation score according to a hospital protocol. Neither patient required further analgesia and appeared comfortable throughout. It was, however, very noticeable that twin 1 recovered more quickly and remained alert during the period of observation when compared to his brother.

Prolonged sedation following cleft palate surgery is worrying and this little study allowed me to contrast two different anaesthetic techniques. The combination of propofol and diclofenac provided very satisfactory operating conditions and fast postoperative recovery and should be considered for surgery on the upper airway.

Royal Hospital for Sick Children,
Glasgow G3 8SJ

W.A. McFadzean

Glycine absorption and visually evoked potentials

Eyesight disturbances and alterations in visual evoked potentials are parts of the transurethral resection syndrome (TUR syndrome) that were recently studied by Mantha *et al.* (*Anaesthesia* 1991; **46:** 491–3). Most authors agree that these effects can be explained by the role of glycine as an inhibitory neurotransmittor in the retina and the brain. Dr Mantha and co-workers found no visual disturbances but a significant prolongation of the p_{100} latency, which was considered to be a toxic effect exerted by the 1.5% glycine solution used to irrigate the bladder during operations. However, their conclusion assumes that a significant amount of the glycine solution was absorbed by the patients, and we do not know if this occurred. The presented data (serum sodium was not changed) rather denies the existence of such pick-up of fluid.

Absorption of irrigating fluid is common during transurethral resection, but it does not occur in every patient. In this hospital, we routinely use glycine solution containing a small amount of ethanol (1%) to detect fluid absorption. [1, 2]. More than 700 patients have been monitored in this way since 1986, and it appears that only about a third of those who undergo transurethral prostatic resection absorb irrigating fluid in any significant amount. Zero absorption was found in many consecutive series of patients exceeding the number of cases studied by Dr Mantha and co-workers. Even though it is true that absorption of less than 100–150 ml of fluid cannot be detected by measurement of breath ethanol or serum sodium [2, 3], the enrichment of glycine in the blood resulting from such low-grade absorption is likely to be very small [4].

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A reply

Thank you for the opportunity of replying to Dr Hahn's letter. We appreciate his interest in our publication and the comments made. Dr Hahn appears to have expressed concern over two issues in our article. They are, significant prolongation of the p_{100} latency with no visual disturbances and the conclusion that the observed alteration in visual electrophysiology was due to glycine absorption, while no changes occurred in serum sodium levels. We will address each of them.

Prolongation of the visual evoked potential (VEP) latency need not necessarily be associated with subjective visual disturbances. For example, patients with subclinical multiple sclerosis have a prolonged VEP latency but normal vision [1]. In a recent study by Casey *et al.* quoted in our article, there was also a significant prolongation of p_{100} latency without visual disturbances after transurethral resection of the prostate (TURP) with glycine irrigation.

Absorption of the irrigating fluid during TURP results from opening up of the prostatic venous sinuses located at the subcapsular plane of the prostate gland. Advancing the resectoscope past the capsule and venous sinuses may result in periprostatic and retroperitoneal accumulation and slow absorption from there. Therefore limiting the resection just up to the capsule of the gland (a variable factor depending upon the expertise of the surgeon) may not result in irrigating fluid absorption at all. This factor might have a role in Dr Hahn's large series in whom zero absorption was observed.

Glycine absorption need not always result in hyponatraemia. Increases in serum glycine levels to more than 4000 μmol.l^{-1} were observed without concomitant change in serum sodium levels [2]. In fact, one of Dr Hahn's original studies revealed that in the development of low serum sodium level typical of a severe TUR reaction, rapid massive absorption is more important than a large total absorbed volume [3]. Review of the literature on the subject reveals that only patients with visual disturbances had hyponatraemia indicating massive absorption. Since diazepam, which can increase the VEP latency, was not administered in our study and the anaesthetic technique included a saddle block, we assumed that glycine absorption accounted for the observed changes in visual electrophysiology. Perhaps in our group of patients, there could have been glycine absorption sufficient to cause a prolonged VEP latency (detected by a very sensitive stimulus-pattern shift) but insufficient to cause subjective changes in the vision. Of course our study is limited by lack of serum glycine level measurement and also a method to monitor irrigating fluid absorption.

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The management of accidental dural puncture in labour

If accidental dural puncture (ADP) occurs whilst attempting epidural analgesia in labour the management recommended by textbooks of obstetric anaesthesia is to resite the catheter at another interspace and this would seem to be common practice [1].

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technique. Crawford [2] reported 302 such cases: following catheter resiting, test doses identified two subarachnoid blocks, but no total spinal or unexpectedly high blocks occurred. On the other hand, Hodgkinson [3] reported three total spinal anaesthetics in his series of 31 patients whose catheters had been resited at an adjacent interspace following ADP. Similarly, Collier [4] described three cases of subdural block occurring after catheter replacement in 59 patients. Even apparently normal epidural analgesia after resiting may be falsely reassuring. Park [5] described a case of high block with marked hypotension following a 4 ml epidural top-up 3.5 h after ADP and catheter resiting. Investigating a similar case, Leach and Smith [6] obtained radiological confirmation that local anaesthetic had spread into the subarachnoid space from a catheter resited epidurally. Attempts to resite the catheter may of course lead to further ADP and one eminent author [7] has stated that when this occurs epidural analgesia should be abandoned and other methods used. Where does this leave the patient who has requested epidural analgesia because other methods have proved inadequate?

An alternative is deliberately to insert the catheter into the subarachnoid space and we have managed two ADPs in this way, providing analgesia for labour by a continuous subarachnoid technique. Possible advantages of doing this are that the anaesthetist is sure of the catheter's position, analgesia should be achieved with a very small dose of local anaesthetic, the block could easily be extended to provide anaesthesia for Caesarean section or forceps delivery. Unfortunately, insertion of the catheter does not reduce the incidence of headache in parturients [8]. Continuous subarachnoid analgesia for labour has been described previously [9, 10].

This is not a new technique and has been reported before [8, 11] but we are surprised that it has not been debated in print in the light of the available literature. We would be interested to hear of others' experience with this method of managing ADP in labour.

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A technique to avoid dural puncture by the epidural catheter

Drs Hughes and Oldroyd recommend a technique to avoid a 'potential' problem associated with the double needle technique of combined subarachnoid and epidural block (*Anaesthesia* 1991; **46:** 802).

Unfortunately the technique described of rotating the Tuohy needle through 180° is associated with a documented incidence of dural puncture. Meiklejohn [1] described a study which showed that rotation of the epidural needle significantly decreases the force required to produce a dural puncture. Hollway and Telford's study [2] on intentional dural puncture with a Tuohy needle showed that 10% of their patients had successful dural punctures when the needle was rotated within the epidural space without being advanced further.

I disagree with the authors and would suggest that the theoretical advantages of Rawal's technique do not outweigh the published hazards of rotating a Tuohy needle within the epidural space.

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Focal seizure following enflurane

We wish to report the following incident. A-50-year-old man presented for arthroscopy and meniscectomy. He gave an 8-day history of low back pain, for which he had taken methocarbamol (Robaxin, Wyeth) 5 days before his admission. He was otherwise fit and was taking no other medication.

No premedication was ordered. Anaesthesia was induced with thiopentone 350 mg and alfentanil 750 μg intravenously and maintained with 1.5 — 2% enflurane in nitrous oxide and oxygen (30%) breathed spontaneously. Surgery proceeded uneventfully, lasted 40 min, and the patient awoke in recovery 5 min after the end of the operation. A few minutes later his left arm, shoulder, and cheek were noticed to be twitching. Although distressed, his level of consciousness was not impaired, and throughout he was able to answer simple questions. Increments of diazepam totalling 20 mg were given intravenously and resulted in a diminution of the twitching. However, a further 10 mg were needed some 30 min later before the movements were totally abolished.

On further questioning the patient stated he had taken a single dose of methocarbamol 5 days before the anaesthetic, but had then developed a twitching of his left arm which subsequently resolved. A diagnosis of a focal seizure with retained consciousness was made by a consultant physician who did not consider that an EEG or CT scan were indicated in the absence of focal signs or unprovoked seizures. To date the patient has suffered no further episodes.

We believe this case to be of interest for three reasons. Firstly, this report would seem to be the first describing a purely focal event occurring without loss of consciousness. Seizures in the postoperative period following enflurane anaesthesia are well documented [1–4]. However, there has been only one previous report of a seizure without loss of consciousness, and this consisted of generalised myoclonic jerks [5].

Secondly, there is the possibility of an interaction with methocarbamol which is promoted for the treatment of acute musculoskeletal disorders, and has a plasma half-life of 2 h [6]. There have been two cases of convulsions following methocarbamol reported to the Committee on Safety of Medicines (Personal communication Ms S. Faithful, Wyeth Laboratories). It seems unlikely, given the short half-life, that methocarbamol was exerting any pharmacological effect in the patient reported at the time of the anaesthetic. However, since he had suffered a focal seizure, a continuing electrical susceptibility to a recurrence may have remained at the time enflurane was administered.

Thirdly, there is evidence that diazepam may potentiate enflurane induced electroencephalographic seizure activity [3], and some have concluded that phenytoin or valproate should be used to treat enflurane induced seizures [5]. In our case diazepam eventually controlled the seizure, although only after repeated doses totalling 30 mg.

Whilst it is possible the patient is harbouring a focal structural lesion, we think this unlikely. He has not developed any focal signs on follow-up, and his seizures only occurred when he was exposed to known epileptogenic drugs. Unusual reactions to drugs may have implications for the anaesthetic technique.

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Methaemoglobinaemia and pulse oximetry

We were interested to read the letter ‘Prilocaine associated methaemoglobinaemia and pulse oximeter’ by Marks and Desgrand (*Anaesthesia* 1991; **46:** 703). The authors state that after surgery had begun the patient appeared dusky and ‘the pulse oximeter showed a saturation of 75%’. They also make the observation that the methaemoglobin level was 6.6%. These statements are misleading because in the presence of severe methaemoglobinaemia, the pulse oximeter reading tends towards 85%.

Pulse oximeter readings in the presence of methaemoglobin causes a shift towards 85% and do not usually go below this value. The reason this shift occurs is explained by the fact that methaemoglobin absorbs strongly at both the oxyhaemoglobin wavelength (940 nm) and deoxyhaemoglobin wavelength (660 nm). The pulse oximeter determines the ratio of pulsatile absorbances at these two wavelengths and as the ratio approaches unity, the pulse oximeter saturation becomes 85%. Hence in situations of severe methaemoglobinaemia, the patient may have drastically reduced saturation in the presence of less alarming oximeter saturation readings. Furthermore, studies in dogs indicate that pulse oximeters begin to show spurious readings at a methaemoglobin level of about 30–35%, at which values the readings are 82–85% and then become virtually, independent of the methaemoglobin level [1, 2]. Therefore, the cited patients’ methaemoglobin level was not significant enough substantially to alter pulse oximeter readings and hence another explanation must exist for her observed saturation reading of 75%.

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Nitrous oxide should not be used during laparoscopy nor during other abdominal operations

I write to second Dr G. Verheecke’s questioning of the wisdom of the use of nitrous oxide during laparoscopic cholecystectomy (*Anaesthesia* 1991; **46:** 698).

For 25 years anaesthetists (and ‘anaesthesiologists’!) seem to have ignored, and seem to be continuing to ignore, the important work of Eger and his team at the University of California as quoted by Dr Verheecke. Eger showed that the administration of nitrous oxide makes the intestines increase in size because nitrous oxide, with its high solubility, gets into the bowel faster than the normal bowel gases (nitrogen and methane) can get out. There have been even more recent papers confirming Eger’s ideas, yet anaesthetists all over the world continue to administer nitrous oxide as if it were required by our religion, even in operations when we know that its administration is going to make the bowel size greater and, therefore, make the surgeons’s job harder!

Dr Verheecke asks ‘Why not avoid nitrous oxide by using total intravenous anaesthesia’? That may be all very well, but I would ask too, ‘Why not use old-fashioned general anaesthesia with 1.0 or 1.5 MAC *in oxygen*, of a good strong volatile agent?' In the recent British literature, a report even showed that during colonic surgery, the use of nitrous oxide actually *delayed* the recovery of bowel function and the patients' discharge from hospital [1].

My appeal to your readers, and my advice is, eschew nitrous oxide in all abdominal cases. Just increase the amount of the volatile agent by 50%. Patients may take 120 s more to awaken but your surgeons will praise you!!

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Reference

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Heel blisters and epidural analgesia for postoperative pain relief

We would like to highlight a hazard inherent in continuous epidural analgesia techniques for postoperative pain relief. Continuous epidural analgesia for the first 24 to 48 h postoperatively is routine in our hospital for the provision of postoperative pain control in patients undergoing major gynaecological or abdominal surgery returning to the ward. The technique employed is bupivacaine 0.1% solution with added fentanyl (2 μg.ml^{-1}) infused epidurally at a rate of 10–12 ml.h^{-1}. This usually results in an excellent sensory block with preservation of motor function. Patients are actively encouraged to move their legs frequently as prophylaxis against deep venous thrombosis.

Over the past year, there have been 12 patients who have suffered from severe heel blisters after surgery. On questioning these patients, all have actively flexed and extended their knees while immobilised in bed. This has obviously resulted in friction burns to the skin over the heels, but because of sensory analgesia no pain is felt while tissue damage is occurring. We would recommend either the use of heel pads or alternatively static isotonic contraction exercises of the calf muscles postoperatively in patients having continuous epidural analgesia.

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Epidurals: a comparison of approaches

The article by Mannion *et al.* (*Anaesthesia* 1991; **46:** 585–7) makes no mention as to whether the epidurals were performed by the midline or paramedian approach. The paramedian approach has been shown by Jaucot [1] to have a significantly lower incidence of vessel catheterisation by the catheter (1.5% versus 5.6% for the midline approach). Blomberg *et al.* [2] did not show any difference in their study, but they only looked at 50 epidurals. Jaucot [1] suggests the lower incidence of vessel catheterisation with the paramedian approach is due to the proximity of the venous plexi which lie on either side of the midline. If the point of entry of the needle is paraspinal the catheter runs up between the two plexi. Certainly, the course of an epidural catheter introduced by the midline route is diverse and unpredictable, whereas the catheter appears to travel in a straight cephalad direction when the paramedian approach is used [3]. If the epidurals in Mannion *et al.*'s study were performed in the midline, then the incidence of complications from epidural analgesia could be further reduced by encouraging the greater use of the paramedian technique.

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Oversedation with patient controlled analgesia

The evaluation of the Graseby PCAS machine by Dr Jackson *et al.* (*Anaesthesia* 1991; **46:** 482–5) includes a description of the green light on the machine, used by patients to maximise the delivery of opioid in anticipation of painful procedures. We too have found the light to work to the patient's advantage; however, caution must be exercised in counselling patients as the following case illustrates.

A 47-year-old patient with carcinoma of the rectum was admitted for proctectomy and hysterectomy. She had no relevant medical or surgical history. General anaesthesia, supplemented by epidural analgesia via a lumbar catheter was uneventful and the initial postoperative course was satisfactory; analgesia was maintained with an infusion of bupivacaine 0.167% and diamorphine 0.2 mg.ml^{-1} at 4 ml.h^{-1}. Patient-controlled analgesia (PCA) was substituted after 16 h as pain resulted from the accidental removal of the epidural catheter. A full explanation of the use of PCA including the function of the green light was given to the patient who apparently understood. Satisfactory analgesia was resumed using morphine, with a loading dose of 5 mg, a bolus of 1 mg, and a lockout interval of 5 min. The patient was comfortable when reviewed 2 h later.

We saw the patient the following morning when the nursing staff remarked on unusual drowsiness. On examination, she was sedated but rousable and sensible; respiratory rate was 13 beat.min^{-1}. She denied pain except on movement. She had used 96 mg of morphine in 20 h (30 mg in the last 4 h). During our examination the patient noticed the green light had become illuminated and she immediately pressed the button. On further questioning, it was clear that she thought that the green light was an indicator to request more analgesia to stay pain free. After further explanation, PCA was continued. Sedation was less as demands fell; satisfactory pain scores were reported. We are confident in this case that sedation was the result of the PCA administration. Nevertheless, caution must be used when neuraxial and systemic opioids are used together.

We have simplified our patient instruction to an explanation of the equipment and the advice 'Push the button when pain is troublesome' leaving patients to discover the green light themselves. As PCA becomes widely used, the need for clear, consistent patient instruction is apparent; the importance of regular, close supervision of therapy is further highlighted by this case.

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Fatal theophylline poisoning with rhabdomyolysis

We read with interest the case report by Parr and Willatts (*Anaesthesia* 1991; **46:** 557–9) of a fatal theophylline poisoning with massive rhabdomyolysis. We wish to bring to the authors' attention an additional case report of rhabdomyolysis following aminophylline overdose in a 16-year-old girl [1]. Our aminophylline overdose patient would not say what she had taken and showed no symptoms on admission. The first indication of severe problems was overnight anuria, followed by convulsions and then unexpected cardiac arrest on the medical ward. A very high potassium was treated by the usual immediate methods, followed by dialysis via an extracorporeal circulation, but further treatment was abandoned when insufficient cardiac output could be obtained to wean off the bypass machine. Sequential blood samples showed a progressive rise of serum myoglobin to $120\,000\ \mu g.l^{-1}$ at death (normal range $6–85\ \mu g.l^{-1}$) and potassium of $12\ mmol.l^{-1}$. Postmortem examination revealed massive histological rhabdomyolysis. The blood samples we obtained had been saved by the pathology laboratory and frozen whole, which did not affect radioimmunoassay of serum myoglobin but made CK assay impractical. Potassium values were obtained from analyses performed on the specimens during the management of the patient.

Our system for keeping laboratory specimens was only partially sucessful, as is witnessed by the freezing of specimens before separation of plasma. However, an effective system to save pathological specimens is essential if the full educational value of unusual cases is to be realised and possibly to be written up for publication. If any serum and urine specimens from the Parr and Willatts case have still been kept, analysis for serum and urine myoglobin might reveal some information on the renal damaging threshold of myoglobin, something which has been eluding medical science for many years.

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Reference

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Apparent anuria

Measurement of urine output and ensuring a constant flow is an important aspect in the maintenance of 'millieu interior' of patients undergoing prolonged surgical operations with loss of blood. In the case of a patient kept in the supine position, a Foley's catheter with its balloon pulled up to the internal ureteric orifice, as usually performed by the nursing staff, helps to measure the urine output of the patient from the very outset of the operation, as the internal ureteric orifice is at the most dependent position of the bladder. However, when a patient is in the prone position, as in posterior spinal surgery, the interior ureteric orifice will be at a superior position to the pool of urine collected in the dependent lax urinary bladder. In this position, a Foley's catheter with the balloon pulled up to the internal ureteric orifice may not drain any urine until the bladder is quite full and it may take several hours to fill the bladder. In the meantime, the anesthetist may interpret lack of urine flow as anuria and take corrective measures to restore urine output.

Therefore, before a patient is positioned in the prone position, it is important to make sure that the catheter is pushed into the bladder to a length of about 6.0 to 8.0 cm, so that urine will be syphoned out from the outset of the operation. If this is not done, the unwary anaesthetist, who has worked hard to correct apparent anuria, will be rewarded with a gush of urine into the urine bag, when the patient is turned over after the operation.

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Further problems with thiopentone solution

We read with interest the recent letters (*Anaesthesia* 1991; **46:** 74 and 602) [1, 2] regarding the problems with precipitate from reconstituted thiopentone. We would like to report a further unusual problem which occurred while mixing thiopentone. Using a sealed system, 5 g of thiopentone was mixed with 200 ml of normal saline stored at room temperature. The resultant mixture immediately produced a white flocculent precipitate, which remained insoluble on standing. While we have heard anecdotal reports of this phenomenon we are unaware of any published reports and few anaesthetists seem to be aware of this problem.

Sodium thiopentone is the soluble sodium salt of thiopentone acid (5-ethyl-5(1-methylbutyl)-2thiobarbituric acid) which is itself insoluble in aqueous solutions. The unconstituted power is produced in sealed nitrogen-filled containers which provide a dry, inert atmosphere. Atmospheric carbon dioxide will readily precipitate the acid from an aqueous solution [1] and it would therefore appear likely that in this case the thiopentone powder was exposed to both carbon dioxide and water vapour. The matter was raised with the manufacturers, who had only ever received one previous similar report. They agreed that the probable cause was a defective seal on the bottle.

We have encountered this problem with two different brands of thiopentone, the one described above and the other with a 500 mg ampoule. While the shelf-life of thiopentone may be many years [2] it would appear that the competence of the seal is the major factor in its preservation.

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Making up inotrope solutions

I have a suggestion concerning the administration of inotropes via a 50 ml syringe and driver. Many units use the formula of putting an amount of drug, measured in milligrams, equal to three times the body weight, measured in kilograms, and making this up to exactly 50 ml. This produces a convenient concentration so that one ml per hour is equivalent to $1 \mu g.kg^{-1}.min^{-1}$. However, this can be very wasteful if the unused drug in the vial is discarded; with dobutamine usage in some units exceeding £40 000 per annum, it is very wasteful to discard up to 15% of the drug.

Instead, why not use the whole contents of the vial and vary the final volume of the solution so that the same concentration is produced. To give $1 \mu g.kg^{-1}.min^{-1}$ for 1 h, the total number of micrograms given in that hour would be equal to the weight in kg times 60. Dividing by 1000 converts the micrograms to milligrams. Since the infusion rate is $1 ml.h^{-1}$ then the concentration of this solution in milligrams per ml needs to be the weight times 60 and divided by 1000. In making up the solution, the amount of drug is known, but it is necessary to know the volume to make it up to in order to achieve the above concentration. Its concentration clearly equals the amount of drug divided by this volume.

Putting the two formulae together gives us:

$$\frac{\text{Weight (in kg)} \times 60}{1000} = \frac{\text{Mass of drug (in mg)}}{\text{Final volume}}$$

Rearranging and simplifying gives us

$$\text{Final volume} = \frac{\text{Mass of drug (in mg)} \times 50}{\text{Weight} \times 3}$$

This formula can be used with any drug and always produces a concentration such that $1 ml.h^{-1} = 1 \mu g.kg^{-1}.min^{-1}$. Clearly, to make double strength solution use either twice the drug in the same volume or the drug made up to half the volume. With some drugs, such as noradrenaline or adrenaline, this 'standard' strength of solution may be impractical or impossible and so much lower concentrations need to be used, say one-tenth strength.

Table 1. Final volumes of solutions of dobutamine and dopamine so that $1 ml.h^{-1} = 1 \mu g.kg^{-1}.min^{-1}$.

Weight (kg)	Final volume (ml) with dobutamine 250 mg	Final volume (ml) with dopamine 200 mg
50	83	67
55	76	61
60	69	56
65	64	51
70	60	48
75	56	44
80	52	42
85	49	39
90	46	37
95	44	35
100	42	33

The table shows the final volumes for selected patient weights of solutions using dobutamine 250 mg or dopamine 200 mg. Since volumes greater than 60 ml will not fit into a 50 ml syringe then double strength solution would need to be prepared. Thus for dobutamine for a 50 kg patient, make 250 mg up to 41.5 ml (instead of 83 ml) to give a solution that $1 ml.h^{-1} = 2 \mu g.kg^{-1}.min^{-1}$.

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Complications following intramuscular diclofenac

A previously fit 59-year-old female presented for elective total abdominal hysterectomy. After an uneventful induction of anaesthesia, 75 mg diclofenac was administered intramuscularly into the lateral aspect of the left thigh. The operative procedure was uneventful and the estimated blood loss was 200 ml. Within 24 h postoperatively, nursing staff noticed a rectangular erythematous area over the lateral aspect of the left thigh, which was subsequently diagnosed as an electrosurgical burn; in addition they noted extensive bruising in the region of the operative site and also her left arm where a blood pressure cuff had been applied intra-operatively. When reviewing her case, we discovered a normal coagulation screen that included platelet count and bleeding time, and we confirmed that the diathermy plate had been applied to the *right* thigh. We concluded that the patient had experienced a local hypersensitivity reaction and an abnormal haemostatic response to the injected diclofenac.

The use of nonsteroidal anti-inflammatory drugs for peri-operative analgesia is now well established. Local skin reactions following intramuscular diclofenac are well known, but in this case we were unable to explain its peculiar shape and can understand the initial diagnosis of electrosurgical burn. Abnormal haemostatic reactions following diclofenac have been discussed by Power *et al* [1], who demonstrated prolonged skin bleeding time and reduced platelet aggregation within 1 h of its injection. The clinical significance of this is doubted, but our patient was obviously sensitive to these effects. With the continued widespread use of these drugs further reactions of this kind can be expected. We still regularly use diclofenac by deep intragluteal injection, as recommended by the manufacturers. Both the patient and her general practitioner were informed of these events.

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Reference

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Aerosol bronchodilator administration distally in a tracheal tube

Several methods of delivering bronchodilator aerosols into a ventilator circuit of an intubated patient have been described [1–4]. These devices deliver the aerosol either before or immediately below the connector. A study by Crogan and Bishop [5] found that only between 3 (SD 1.9) % and 6.5 (SD 4.4) % of a metered dose of aerosol delivered into the circuit at this level reaches the trachea, varying with tube diameter and gas flow. The remainder collects on the surfaces of the connector and tracheal tube [1].

A system we have found clinically effective delivers the aerosol at a point 18 cm down the lumen of the tracheal tube, and is easily assembled from readily available anaesthetic apparatus (Fig. 1). The aerosol cannister (Ventolin inhaler: Allen and Hanbury) is removed from its normal plastic housing and fitted to the inlet of an 8 inch disposable Xylocaine spray nozzle normally used for topical 10% lignocaine (Astra B 0643). This requires a firm twist, but provides a device which allows easy and reliable triggering of the canister. A needle from a 14 gauge intravenous cannula is used to pierce the centre of the plug of a bronchoscopy cap on a Portex swivel connector (Portex 15 mm reusable swivel connector 100/250, with optional fibreoptic bronchoscopy cap). The distal 1 cm of the nozzle is kinked at an angle of approximately 20° in what will be an anterior direction when lying within the tracheal tube, angling the nozzle in the direction of gas flow rather than against the wall of the tube (Fig. 2). The spray nozzle can then be advanced through the plug and down the tracheal tube. The cannister must be used with the delivery port down, as in its normal housing, and one or two puffs should be allowed before the device begins

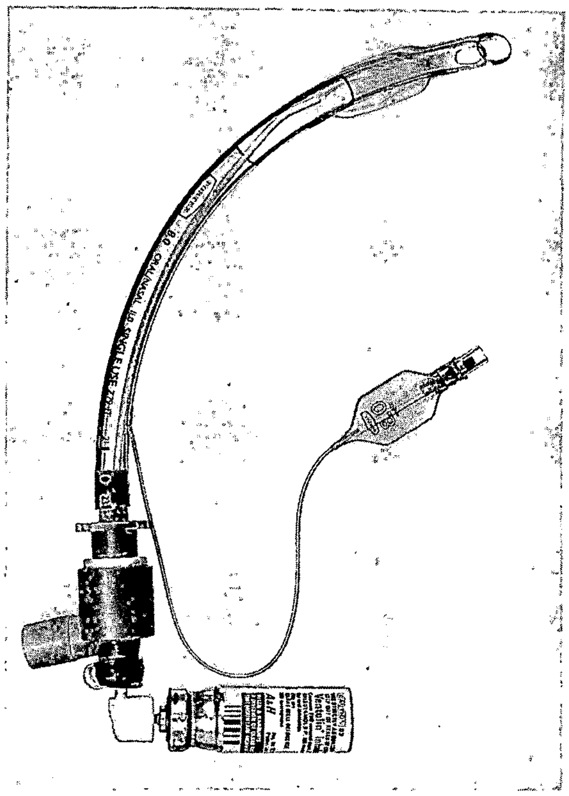

Fig. 1.

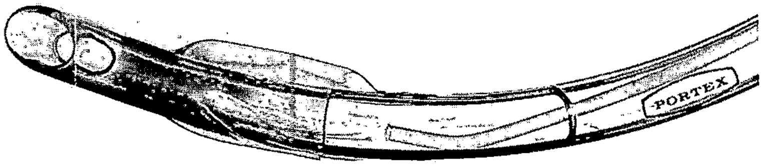

Fig. 2.

delivering aerosol into the tube. The plug still provides an effective seal for the cap after the nozzle has been removed.

In the event of the bronchoscopy cap not being readily available one or more layers of plastic adhesive tape can be used to cover the suction port of the normal Portex swivel connector. Cutting a slightly undersize slit in the tape with a disposable needle allows the spray nozzle to be passed into the tracheal tube. A good seal is achieved with only a very slight leak and the patient can be ventilated with no noticeable loss of airway pressure, allowing the aerosol to be given during an assisted inspiration.

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Book reviews

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A rational basis for anesthesiology

Edited by G. Dal Santo. Pp. 933. Piccin, Padua, Italy, 1990. £48.

As suggested by the title this weighty new book attempts to explain the scientific background to the practice of anaesthesia. This is not a unique approach and follows a path already trodden by texts such as *Scientific Foundations of Anaesthesia.* However, the book does have a number of interesting features worthy of note.

It is written by a single author and therefore has a consistent style which is clear, simple and easy to read, but it does tend to represent a personalised viewpoint. The clarity of style is aided by a large number of illustrations, many of which are excellent and borrowed from other noted texts. However, many of these illustrations, together with some of the topics are repeated, often verbatim, in different chapters, a rather wasteful practise. The text is primarily written for the North American trainee and largely reflects anaesthetic practice in the USA. This is particularly evident in the section on anaesthetic equipment where the discussion of breathing circuits centres almost entirely on circle systems, whilst the Mapleson A system receives a very poor press. Similarly, the Manley ventilator, stalwart of UK anaesthetic practice, gets no mention in an otherwise comprehensive description of anaesthetic ventilators. The text is not extensively referenced, but at the end of each chapter there is a handful of major classic references and suggested reading.

There were a number of disappointing features in the book. There are far too many major errata for a textbook of this type, some of which could confuse and mislead the novice. Another confusing point is that some topics are buried in chapters where you would least expect to find them. For example the discussion of CO_2 physiology is found in the section dealing with anaesthetic equipment! Finally, I strongly disagreed with some of the author's views. I fear that his description of a crash induction would not satisfy the examiners of the FCAnaes!

Overall, a useful book to have in a department library, especially as a source of excellent illustrations, but I do not recommend it to be read as the sole rational basis for anaesthetic practice.

P. Clyburn

Anesthetic and obstetric management of high-risk pregnancy

S. Datta. Pp. 719. Mosby Year Book, 1991.

This latest contribution to the now considerable literature on obstetric anaesthesia takes a problem-orientated approach to the subject. There are 62 contributors to the 30 chapters, with 28 of these having at least one anaesthetist and one obstetrician as author. The doyen of obstetric anaesthesia, Gertie Marx, writes the foreword and states 'this new text initiates a special aspect: collaboration between the specialists involved in the management of difficult delivery'. The impact of the book will, I suspect, be greater for anaesthetists than obstetricians as it seems to be written with anaesthetists in mind.

Seven chapters deal mainly with the fetus, discussing fetal monitoring, fetal hypoxia and different conditions of the sick or at-risk fetus. These chapters will increase the anaesthetist's knowledge of the fetus, thus allowing a more sensible approach to the anaesthetic care and requirements of both mother and baby.

The remaining chapters have the mother as subject, from the teenager, the morbidly obese to the sick mother. Neurological, cardiac, renal, orthopaedic and haematological conditions are only some of those discussed. Most subjects are arranged in a similar and coherent pattern: incidence, aetiology pathophysiology diagnosis and obstetric and anaesthetic management. All aspects are thus dealt with leaving little room for confusion, even if one is not in full agreement with the management. The editor himself distances his own hospital practice from certain recommendations expressed by the authors.

Some information is likely to be new to many clinicians, such as the anaesthetic management of HIV-infected patients. The risk of CNS manifestations, with ultimately up to 50% of patients developing spinal cord involvement with paralysis and ataxia, spells the need for careful neurological assessment before regional anaesthesia. It also stresses the fact that general anaesthesia may further suppress the immune function. But in these patients tracheal intubation may provide the means of infecting the pulmonary tree and also be more difficult to perform with pharyngeal lymphatic hypertrophy. Pregnancy-induced hypertension is covered in an excellent chapter of some 30 pages with over 100 references. It sets out an unequivocal case for epidural anaesthesia and analgesia in the pre-eclamptic patient with commendable clarity. Details are given of coagulopathy, and other maternal and fetal monitoring requirements. Treatment is discussed for intravenous fluid regimens, anticonvulsant magnesium sulphate, but antihypertensive therapy is only discussed under the hypertensive response to tracheal intubation.

This book offers a splendid fund of information. I suggest that every labour ward is encouraged to purchase a copy so that the duty anaesthetist can be encouraged to remain on the labour ward if only to peruse this tome.

B. M. Morgan

Drug and anesthetic effects on membrane structure and function

Edited by R.C. Aloia, C.C. Curtain and L.M. Gordon. Pp. XI+292. Wiley-Liss, 1991. $165.

This is a multi-author volume in the *Advances in Membrane Fluidity* series which is unlikely to become a standard work in Anaesthesia Department libraries. The editors intended this volume to be read by clinicians who do not have a detailed background in physical chemistry or pharmacology. In view of the increasing general interest in the underlying mechanisms of anaesthesia this is a laudable aim, but I suspect that the target audience will be confined to individual research workers with a specific interest in membrane structure and function. This review therefore concentrates on outlining the subject material of the 12 chapters so that the potential reader will know when it is worth requesting it on the interlibrary loan system.

There is an initial short chapter on the role of membrane fluidity in anaesthetic action by Trudell. This is essentially an update of earlier reviews by the same author and as expected it is very readable and a good introduction to anyone unfamiliar with the subject. The interfacial effects of anaesthetics on membrane fluidity are covered by Ueda with the perturbations of membrane structure and function being detailed by Curatola and colleagues. Both of these chapters are written by respected individuals in their fields and include data derived from over 300 papers. A short critical overview on anaesthetics and membranes is provided by Akeson and Deamer, who chose the GABA receptor as an example of a plausible protein site for anaesthetic action. Urry and Sandorfy provide a provocative chapter on the importance of the chemical modulation of the hydrophobic aspects of membranes with the emphasis on the role of hydrogen bonding capacity.

The book is not confined to classical general anaesthetics. Deliconstantinos deals with the perturbations produced by charged drugs while Freisleben and Zimmer review the influences of neuroleptics and tricyclic antidepressants on biological membranes in general. The broad pharmacological definition of anaesthetic effects includes a chapter by Chatelain on amiodarone and related cardiovascular drugs. Wilce and colleagues outline the highly fashionable field of ethanol and neurotransmitter receptor systems. Finally, the volume covers a variety of lipid-protein systems in addition to the neuronal membrane group. These include the red cell membrane (Freisleben and Zimmer), myocardial membrane (Hans and Gross), pulmonary surfactant (Waring and colleagues) and viral fusion proteins (Bentz).

I have deliberately mentioned the individual authors because if the potential reader knows any of their other published work he (she) will be able accurately to anticipate the emphasis of each review. Those not familiar with the field may be impressed by the volume of work (over 1000 publications) in this one area of molecular mechanisms of anaesthesia which is represented by reviewers from laboratories in North America, Australia and Europe. The only disappointment will be the lack of a UK review but Britain is well represented in the seminal contributions in the bibliographic compilations of primary data.

A final general point is that there has been a periodicity in the emergence of new theories of anaesthetic action. In the 1960s the clathrates were the focus of attention, in the 1970s lipid interactions were emphasised while in the 1980s direct anaesthetic-protein interactions were fashionable. It is to be hoped that the 1990s will include a re-evaluation of this cornucopia of ideas, with the development of a consensus on the most likely molecular mechanism of anaesthetic action. As the editors correctly argue, this is not to suppose that the result will be a unifying, all-purpose theory but the scientific dialogue should provide more focused hypotheses for experimental testing.

M.J. Halsey

A colour atlas of dental analgesia and sedation

G.J. Roberts and N.L. Rosenbaum. Pp. 208. Wolfe, 1991. £35.

This profusely and clearly illustrated book deals with local analgesia, inhalation sedation and intravenous sedation and appears at a time when these topics are of great importance to anaesthetists. The Foreword is by David Poswillo whose name is associated with the recent recommendations which aim to limit indiscriminate use of general anaesthesia in dental surgeries and there could be no more appropriate method of preparing dentists for this than the reading of this book. It does not deal with general anaesthesia *per se* but it does cover resuscitation and all the necessary aspects of this.

The first section is written by Graham Roberts who is Reader in Paediatric Dentistry at the United Medical and Dental Schools of Guy's and St Thomas's Hospitals, London and clearly illustrates the most useful techniques for the blocks. This is combined with a brief description of early dental pain, general patient management, equipment and the pharmacology of drugs. While others may use different approaches to nerve blocks certainly those listed here appear safe and limitations and specific uses are discussed.

Less well known to anaesthetists will be the section on relative analgesia (pages 71–99) where not less than 30% oxygen with nitrous oxide is given. It was in this section that the reviewer detected the only mistake in the book. The stages of anaesthesia are referred to as the stages of analgesia (figure 140).

The final section of the book deals in detail with intravenous sedation and touches aspects which anaesthetists are unaware of such as the organisation of sedation sessions, selection of suitable patients and the dental surgery team. It contains a brief but adequate review of anatomy and the pharmacology of benzodiazepines and there is a very clear description of techniques written by someone who obviously has wide experience in this field. One might criticise the emphasis on the role of flumazenil in this field with no suggestion that it might lead to sloppy sedation techniques. Apart from this omission it is an extremely valuable section.

On reading through the book one becomes aware of the basic difference in the training of anaesthetists and that of dentists who practice the specialty. So many things are discussed here which we would take for granted and one can quite appreciate that being the occasional sedationist is a less than desirable situation.

On the whole this would be a very useful bench book for many surgeries and should be standard in the library of every dental school.

J.W. DUNDEE

The design of analgesic clinical trials (Advances in pain research and therapy, Vol. 18).

Edited by M.B. MAX, R.K. PORTENOY AND E.M. LASKA. Pp. 751. Raven Press, New York. $152.50.

It is often claimed that anaesthetists should do some research, particularly drug related, during their training so that they may better understand how to assess the results of trials, the onslaught of the drug companies and publications in journals. Others have taken the view that most of this research is poorly conducted, wastes resources and is of little value to the individual other than to enhance their curriculum vitae and improve appointment prospects. Instead they believe that anaesthetic departments should run well-conducted journal clubs and meetings to help the majority, and research time should only be given to those prepared to devote a substantial period of time and effort to a project. *The design of analgesic clinical trials* certainly confirms this latter view. Three editors and 63 contributors in 32 chapters and 751 pages have combined to produce a formidable review of the many problems involved in analgesic drug trials. Even so, this is not a complete picture since the reader is advised to consult 'a biostatistician when planning, analyzing and interpreting clinical trials'.

The book is in three parts: the steps in the clinical evaluation of an analgesic which reviews various pain models including a nice contribution by Henry McQuay on N of 1 trials; the design of analgesic studies to meet specific clinical needs, ranging from back pain to chronic orofacial pain, sore throat to dysmenorrhea, and spinal opioids to PCA; the third section includes pharmacokinetics, training of observers, the practicalities of running drug trials as regulated by the Food and Drug Administration in the United States and a chapter on issues in designing trials of nonpharmacological treatments of pain.

The design of analgesic clinical trials is part of the Advances in Pain Research and Therapy series which in the past has published proceedings of international pain meetings as well as volumes, like this one, devoted to specific topics and not meeting reports. These latter tend to be very variable in quality and lose their value rapidly. *The design of analgesic clinical trials* is not in this category. It is a book which can stand in its own right and should be in the library of every department contemplating analgesic drug trials. It also is excellent material for a 'journal club'.

L. STRUNIN

International anesthesiology clinics. Interdisciplinary pain management

Edited by P.W. LEBOWITZ. Pp. 109. Little, Brown & Company, 1991. $39.

This is quite an interesting little book, but not much of it is about interdisciplinary pain management. The first chapter describes interdisciplinary pain management and explains that it is an effective way of treating the sufferer from pain. The second chapter then describes the evolution of the psychological methods that now play such an important part in the modern Pain Clinic. The book then becomes almost entirely medical, discussing acute pain, back pain, reflex sympathetic dystrophy, orofacial pain and the role of neurolytic blocks in cancer (not you note the management of pain in cancer) as if these were exclusively the domain of the clinician and not best dealt with as the first chapter would suggest, by an interdisciplinary team.

The interdisciplinary team that the author describes has the same make-up as that functioning in most of the developed pain clinics in the UK, namely a clinician almost always an anaesthetist, a psychologist, a nurse (soon one hopes a nurse specialist) a physiotherapist, and perhaps an occupational therapist. This team can do much more for back pain than treat it only with steroid epidurals, but apart from a short section on conservative management this book suggests nothing else. What about myofascial pain, the facet joints, surgery and the different methods of stimulation analgesia? The same interdisciplinary team would find an approach to chronic orofacial pain that centred exclusively around temporo-mandibular joint dysfunction failing to help in the majority of cases that present to the clinic. The approach to reflex sympathetic dystrophy is more comprehensive, but still makes no mention of the place of the psychologist in this confused area, while there is so much more to the relief of pain in the dying than neurolytic blockade that this chapter should not be in this book. The chapter on acute pain is interesting as it dwells on the most baffling question that confronts us, why do we not apply the methods that have been available for years to us and work? Why don't we care that people suffer through our failure to relieve the suffering? This is followed by a small section on the still unresolved issue of the changes in the central nervous system that result from prolonged noxious stimulation, and whether these can be prevented. There is nothing about interdisciplinary teams to deal with acute pain relief. The chapter on paediatric pain is similarly limited, though interesting and well written.

Is the book worth reading? The first chapter on interdisciplinary pain management, though turgidly written,certainly is, and with the same reservations, the chapter on psychological aspects. The acute pain chapter is interesting, but has little originality, as to the rest, it is better and more comprehensively discussed elsewhere.

A.W.DIAMOND

Books received

We thank the publishers for the following books, some of which may be reviewed in future issues of *Anaesthesia.*

Neuroanesthesia: handbook of clinical and physiologic essentials, 2nd edn.

Edited by P. NEWFIELD AND J.E. COTTRELL. Pp. 400. Little, Brown, 1991. £35.00.

Anesthesia for ambulatory surgery, 2nd edn.

Edited by B.V. WETCHLER. Pp. 690. J.B. Lippincott, 1991. $75.00.

Handbook of local anesthesia, 3rd edn.

Edited by S.F. MALAMED AND C.L. QUINN. Pp. 322. Mosby Year Book, 1991, £28.00.

Anesthesia for plastic and reconstructive surgery

Edited by A.R. ABADIR AND S.G. HUMAYUN. Pp. 467. Mosby Year Book, 1991.

Principles and practice of neuroanaesthesia

Edited by N. EDWARDS. Pp. 534. Chapman and Hall Medical, 1991.

Drugs in anaesthetic practice, 7th edn.

Edited by M.D. VICKERS, M. MORGAN AND P.S.J. SPENCER. Pp. 537. Butterworth Heinemann, 1991.

Mechanical ventilation and assisted respiration

Edited by A. GRENVIK, J. DOWNS, J. RASANEN AND R. SMITH. Pp. 300. Churchill Livingstone, 1991. £22.50.

Anaesthesia, 1992, Volume 47, pages 89–90

Obituaries

Dalal, S.D., MB, BS, FFARCS. Formerly Consultant Anaesthetist North Middlesex Hospital. Qualified from Seth GS Medical College, Bombay in 1947.

Russell, M.D., MRCS, LRCP, FFARCS. Formerly Consultant Anaesthetist Plastic Surgery and Jaw Injury Centre, Queen Victoria Hospital, East Grinstead. Qualified from London University (Westminster) in 1940.

International congress calendar

1992

17–18 January. Leuven, Belgium. *International Symposium on Developments in Special Anesthetic Techniques.*
Information: Secretariat, Department of Anesthesiology, Katholieke Universiteit Leuven, Universitaire Ziekenhuizen Leuven, Herestraat 49, B-3000 Leuven, Belgium.

18–21 January. Acapulco, Mexico. *10th Annual Symposium Clinical Update in Anesthesiology.*
Information: Helen Phillips, Mount Sinai Medical Center, 1 Gustave L, Levy Place, Box 1010, New York, NY 10029-6574, USA.

19–21 January. Honolulu, Hawaii. *Second American–Japan Anesthesia Congress.*
Information: Vicky Larsen, Department of Anesthesiology, University of Utah School of Medicine, 50 North Medical Drive, Salt Lake City, UT 84132, USA.

19–25 January. Maui, Hawaii. *Hawaiian Seminar.*
Information: California Society of Anaesthesiologists, 1065 East Hillsdale Boulevard, Suite 410, Foster City, California 94404-1615.

22–26 January. Acapulco, Mexico. *4th International Symposium, Anesthesia for Cardiac Patients.*
Information: Helen Phillips, Mount Sinai Medical Center, 1 Gustave L, Levy Place, Box 1010, New York, NY 10029-66574, USA.

24–26 January. Los Angeles, USA. *30th Clinical Conference in Pediatric Anesthesiology.*
Information: Katherine Barky, Program Director, Pediatric Anesthesiology, Children's Hospital of Los Angeles, PO Box 54700, Los Angeles, CA 90054, USA.

1–8 February. Colorado. *18th Annual Vail' Conference in Anaesthesiology.*
Information: Sonja Craythorne, Professional Seminars, P.O. Box 012318, Miami, Florida 33101, USA.

1–8 February. Steamboat Springs, Colorado, USA. *New Horizons in Anesthesiology.*
Information: Ms Kathleen A. Maitland, Department of Anesthesiology, Emory University at Crawford Long Hospital, 25 Prescott Street, 5405 Glenn Atlanta GA 30308, USA.

8–14 February. Cooper Mountain, Colorado, USA. *Anesthesia Update 1992.*
Information: Alan H. Goldberg, Department of Anesthesiology, Medical College of Wisconsin, 8700W Wisconsin Avenue, Milwaukee, Wisconsin 53226, USA.

15–22 February. Whistler, BC, Canada. *Ninth Annual Winter Seminar.*
Information: California Society of Anesthesiologists, 1065 East Hillside Boulevard, Suite 410, Foster City, California 94404-1615, USA.

21–23 February. Hakes Bay, New Zealand. *Local and Regional Anaesthesia.*
Information: Dr R. Chisholm, Department of Anaesthesia, Memorial Hospital, Hastings, New Zealand.

28 February–2 March. Vail, Colorado. *Principles of Anesthesia Technology Workshop.*
Information: Carolyn Johnson, Office of Continuing Medical Education, 4200 East 9th Ave, Box C295, Denver, CO 80262, Colorado, USA.

29 February–7 March. Vail, Colorado. *Colorado Review of Anesthesia.*
Information: Carolyn Johnson, Office of Toninuing Medical Education, 4200 East 9th Avenue, Box C295, Denver, CO 80262, Colorado, USA.

3–6 March. Boston, Massachusetts. *14th Annual Meeting, Society of Cardiovascular Anesthesiologists.*
Information: SCA, PO Box 11086, Richmond, VA 23230-1086, USA.

13–17 March. San Francisco. *66th Congress of the International Anesthesia Research Society.*
Information: Anne F. Maggiore, International Anesthesia Research Society, 2 Summit Park Drive, Suite 40, Cleveland, Ohio 44131, USA.

23–27 March. Brussels, Belgium. *12th International Symposium on Intensive Care and Emergency Medicine.*
Information: Suzanne Smitz-de-Smet, Symposium Manager, Department of Intensive Care, Erasme University Hospital, Route de Lennik 808, B-1070, Brussels, Belgium.

25–29 March. Tampa. *17th Annual Meeting of the American Society of Regional Anesthesia.*
Information: ASRA. PO Box 11086, Richmond, Virginia, 23230–1086, USA.

29 March–2 April. Atlanta, Georgia. *The Third International Symposium on the History of Anaesthesia.*
Information: R.K. Calverley, Medical Center, University of California, 225 Dickinson Street, San Diego, California CA 92103, USA.

1–3 April. Bristol. *Junior Anaesthetists' Group Linkman Conference and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London, WC1B 3RA, UK.

23–25 April. Atlanta, Georgia, USA. *2nd International Symposium on Memory and Awareness in Anesthesia.*
Information: Ms Kathleen A. Maitland, Department of Anesthesiology, Emory University at Crawford Long Hospital, 25 Prescott Street, 5405 Glenn, Atlanta GA 30308, USA.

2–6 May. Boston. *Society of Cardiovascular Anesthetists.*
Information: PO Box 11086, Richmond, Virginia, 23230–1086. USA.

21–24 May. Montreal, Canada. *4th International Neuromuscular Meeting.*
Information: Clair Diano, Post-Graduate Board, Royal Victoria Hospital, 687 ouest, Avenue des Pins, Montreal, Quebec H3A 1A1, Canada.

5–9 June. Toronto. *49th Annual Meeting of the Canadian Anaesthetists' Society.*
Information: Ms Kara Kieferle, Meeting Coordinator, 187 Gerrard Street E, Toronto, Canada M5A 2E5.

7–12 June. Barcelona. *Anestesia 92.*
Information: Pacifico, S.A.: c/Muntaner, 112-08036 Barcelona, Spain.

9–12 June. Brussels, Belgium. *4th Joint Meeting, European and American Societies of Regional Anesthesia.*
Information: ESRA, Dr van Zundert, Kempenlaan 12, B-2300 Turnhout, Belgium or ASRA, PO Box 11086, Richmond VA 23230-1086, USA.

10–12 June. Rotterdam, The Netherlands. *13th International*

Symposium on Computer Assisted Decision Support and Database Management in Anesthesia, Intensive Care and Cardiopulmonary Medicine.
Information: Dr Omar Prakash, Thorax Centre, Erasmus University, 3000 DR Rotterdam, The Netherlands.

10–13 June. Brussels. *European Society of Regional Anaesthesia (UK) Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

11–14 June. Marco Island, Florida. *Annual Meeting of the Florida Society of Anesthesiologists.*
Information: Florida Society of Anesthesiologists, 6501 25 Ways Street, Ste D, St Petersburg, FL 33712, USA.

12–19 June. The Hague, *10th World Congress of Anaesthesiology.*
Information: Dr Harm Lip, Nilantsweg 99, 8041 AR Zwolle, The Netherlands.

2–3 July. Bordeaux, France. *Tracheal Intubation.*
Information: Anne-Marie Cros, Département Anesthésie Réanimation, Hôpital Pellegrin, Place Amélie Raba-léon 33076, Bordeaux Cedex, France.

12–16 August. Dunedin, New Zealand. *Intravenous and Inhalational Anesthesia.*
Information: Organizing Secretariat CANZ 1991, Department of Anaesthesia and Intensive Care, Dunedin Hospital, Dunedin, New Zealand.

26–30 August. Poznan, Poland. *European Academy of Anaesthesiology (Open) Refresher Course and (Members only) Scientific Meeting.*
Information: Professor M.D. Vickers, Department of Anaesthesia, University of Wales College of Medicine, Heath Park, Cardiff CF4 4XN, UK.

2–4 September. Southampton. *Ultrasound Angiography 92. 2nd International Conference.*
Information: Conference Secretariat, Ultrasound Angiography 92, PO Box 15, Eastleigh, Hampshire SO5 5XG, UK.

9–11 September. Bournemouth. *Linkman and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London, WC1B 3RA, UK.

14–18 September. Jerusalem, Israel. *5th International Congress, The Pain Clinic.*
Information: Secretariat, The Pain Clinic, PO Box 50006, 61500 Tel Aviv, Israel.

17–20 September. Halkidiki, Macedonia, Greece. *2nd Congress of Anaesthesiology and Intensive Medicine.*
Information: Secretariat, 2nd Congress of Anaesthesiology and Intensive Medicine, PO Box 10058, 54101 Thessaloniki, Greece.

8–10 October. Mainz, Germany. *13th International Congress on Computers in Critical Care and Pulmonary Medicine.*
Information: Professor W. Dick, Klinik für Anästhesiologie, Langenbeckstraße 1, Postfach 3960, 6500 Mainz, Germany.

17–21 October. New Orleans. *American Society of Anesthesiologists Annual Meeting.*
Information: Executive Secretary, ASA, 515 Busse Highway, Park Ridge, IL 60068, USA.

20–21 November. Brighton, UK. *1st CPR Congress of the European Resuscitation Council.*
Information: Dr D.A. Zideman, Department of Anaesthesia and Critical Care, Hammersmith Hospital, DuCane Road, London W12 0HS, UK.

12–16 December. New York. *46th Postgraduate Assembly in Anesthesiology.*
Information: Kurt G. Becker, Executive Director, The New York State Society of Anesthesiologists, Inc., 41 East 42nd Street, Suite 1605, New York 10017, USA.

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30 January–6 February. Aspen, Colorado. *New Horizons in Anesthesiology.*
Information: Miss Kathleen A. Maitland, Department of Anesthesiology, Emory University at Crawford Long Hospital, 25 Prescott Street, 5404 Glenn, Atlanta GA 30308, USA.

12–16 February. Utah. *38th Annual Postgraduate Course in Anesthesiology — 'Anesthesiology: Today and Tomorrow'.*
Information: Vicky Larson, Department of Anesthesiology, University of Utah School of Medicine, 50 North Medical Drive, Salt Lake City, Utah 84132, USA.

14–18 March. Cape Town, South Africa. *South African Society of Anaesthetists Jubilee Congress.*
Information: Mrs S. Elliot, Postgraduate Education Centre, UCT Medical School, Observatory 7925, Cape Town, South Africa.

19–23 March. San Diego, California. *67th Congress of the International Anesthesia Research Society.*
Information: Anne F. Maggiore, Executive Director, International Anesthesia Research Society, 2 Summit Park Drive, Suite 140, Cleveland, Ohio 44131, USA.

29 April–2 March. North Carolina. *Meeting of the Association of University Anesthetists.*
Information: Francis M. James III, Department of Anesthesia, Wake Forest University Medical Center, 300 S. Hawthorne Road, Winston-Salem, North Carolina 27103, USA.

10–13 June. Boca Raton, Florida. *Annual Meeting of the Florida Society of Anesthesiologists.*
Information: Florida Society of Anesthesiologists, 6501 25 Way Street, Ste D, St Petersburg, FL 33712, USA.

1–4 September. Liverpool. *European Course and Congress in Paediatric Anaesthesia.*
Information: Dr P.D. Booker, Alder Hey Hospital, Liverpool L12 2AP, UK.

22–24 September. Glasgow. *Linkman Conference and Annual Scientific Meeting.* Joint Meeting between the Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London, WC1B 3RA.
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London, WC1B 3RA.

9–13 October. Washington DC. *American Society of Anesthesiologists Annual Meeting.*
Information: Executive Secretary, ASA 515 Busse Highway, Park Ridge, IL 60068, USA.

1994

7–9 September. Brighton. *Linkman Conference and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London, WC1B 3RA, UK.

2–7 October. Jerusalem. *European Congress of Anaesthesiology.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London, WC1B 3RA, UK.

1995

13–15 September. Birmingham, Linkman Conference and Annual Scientific Meeting.
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA, UK.

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Hazard Notices

Misuse of a laboratory water bath for warming blood for transfusion HC(Hazard)(91)16

A water bath designed by Grant Instruments for routine laboratory applications was incorrectly used for warming blood for transfusion. The blood was heated to 60°C. This bath does not have the appropriate safety features for use as a clinical blood warmer. Laboratory water baths must not be used for warming blood for transfusion.

Fisher and Paykel dual temperature probes for humidifiers: risk of short circuit HC(Hazard)(91)27

An electrical short circuit could exist on some Fisher and Paykel dual purpose temperature probes used with their humidifier Models MR600 620/630 and 460. The effect of this short circuit is that the humidifier would display a lower temperature than that being achieved at the patient connection.

Recall of Corke–Cranswick percutaneous minitracheostomy tubes and sets from William Cook Europe Ltd: the airway tube may disconnect from the flange (base plate) whilst *in situ* HC(Hazard)(91)31

The manufacturers of these minitracheostomy tubes and sets found that products with an expiratory date of September 1996 or earlier exhibit a sensitivity to body temperature. As a result the airway tube may detach from the base plate whilst *in situ*. Products with codes C-CMTS-100, C-CMTS-200, C-CMTS-200-CD2847 and C-CMTS-2-HANSON and an expiry date of September 1996 or earlier should be withdrawn from user areas and all stocks quarantined immediately. The supplier has issued a recall notice dated 26 September 1991.

Churchill water-heated mattress (Thermocirculator); older types with circular temperature dial: risk of patient burns HC(Hazard)(91)30

A patient suffered severe burns because the temperature of this mattress was too high. Water-heated mattresses made by Churchill Ltd prior to 1982 and which are still in use need to be checked to ensure that the heated mattress is intended for medical use and is fitted with a secondary over-temperature cut-out; the latter is set to operate not higher than 42°C; a stop is fitted to the temperature control so that it cannot be set above 40°C; an audible alarm is fitted to warn users that the secondary temperature cut-out is operating. It is strongly recommended that any new heated mattress meets the medical electrical safety Standard BS5724: Part 1 (1989) or the international equivalent IE601-1 (1988).

Recall due to risk of uncontrolled flow of Critikon Rate-Mate i.v. solution sets with rate-clips flow regulators used with rate-minder i.v. infusion controllers HC(Hazard)(91)29

There are faulty rate-clip flow regulators on rate-mix i.v. administration sets affecting six product codes: 6412 with 2Y-sites; 6422 filter set with 2Y-sites and 0.22 micron filter; 6432 piggyback set with 2Y-sites and backcheck valve; 6442 filter piggyback set with 2Y-sites, backcheck valve and 0.22 micron filter; 6482 burette set with 2Y-sites and 150 ml burette; 6492 nitroglycerin set with 2Y-sites and low absorption tubing.

Portex size 8.5 and 15 mm infant ventilation/breathing systems: manufacturer's recall HC(Hazard)(91)32

A hazard has been identified concerning the use of Portex 8.5 mm infant ventilation/breathing systems where a crack may occur in the 8.5 mm cross piece whilst in use.

Use of the following products should be discontinued:

Portex 8.5 mm infant ventilation breathing systems.
Reference number 100/268/000
Batch numbers GI3257, 89K20AG01, 89H21AG01, 89H23AG01, 89H29AG01, 89K14AG01, 89KAG02, 90B05AG01, 90B06AG01, 90E15AG01, 90G13AG01
Reference number 109/268/010/000
Batch number 90121AG01
Portex 15 mm infant ventilation/breathing systems.
Batch numbers 90C05AG01, 90C05AG02, 90G19AG01
Reference numbers 109/259/010/000
Batch number 90121AG01
Reference numbers 109/273/000/090
Batch numbers 90J15AG03, 91F17AG02

Any such products should be removed immediately from use. Products with the above-mentioned reference and batch numbers should be withdrawn from user areas and stocks quarantined immediately.

Safety Action Bulletin

Physio Control Lifepak 10 Defibrillator Monitor: modification check SAB(91)62

Users should check that all Physio Control Lifepak 10 Defibrillator Monitors prior to serial number 9627 have been modified in accordance with the manufacturers instructions. The modification has been incorporated in units manufactured from serial number 9627.

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Erratum

Anaesthesia, 1991, Volume 46, pages 638–641

A comparison of dopexamine and dopamine to prevent renal impairment in patients undergoing orthotopic liver transplantation

P. A. GRAY, A. R. BODENHAM AND G. R. PARK

Part of Table 2 in the above paper was omitted by the author. The complete table is given below.

Table 2. Urine volumes, urine/plasma osmolality ratios, creatinine clearance values and incidence of renal dysfunction in the two treatment groups. Data are expressed as mean (SD).

	Dopexamine	Dopamine
Urine output; litres	$n = 11$	$n = 12$
0–24 hours	2.35 (0.45)	2.03 (0.80)
25–48 hours	2.21 (1.09)	2.21 (0.60)
Urine: plasma osmolality ratio	$n = 10$	$n = 6$
Pre-operative	2.1 (0.8)	1.5 (0.3)
Postoperative	1.4 (0.3)	1.3 (0.3)
Day 1 after surgery	2.0 (0.5)	1.6 (0.5)
Day 2 after surgery	2.3 (0.1)	2.1 (0.3)
Creatinine clearance (ml/minute)	$n = 9$	$n = 7$
Pre-operative	61.3 (24.1)	51.7 (12.4)
0–24 hours	57.6 (26.2)	58.6 (26.6)
24–48 hours	72.3 (40.5)	55.6 (40.5)
Renal dysfunction		
Renal impairment	3	8
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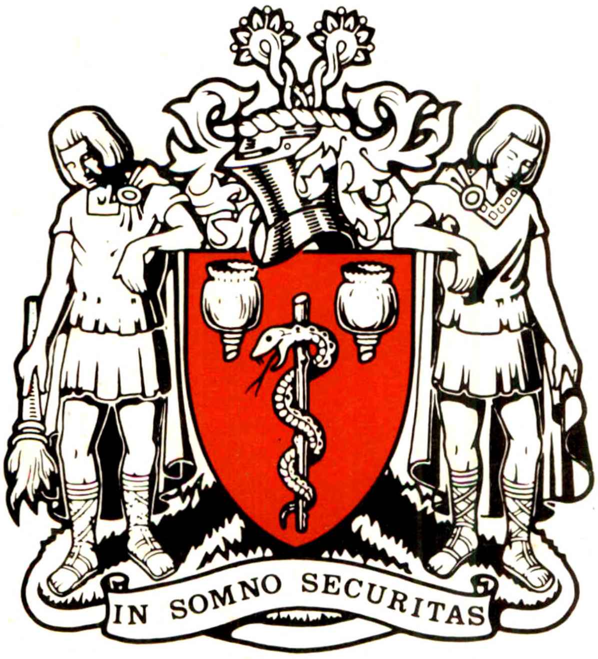

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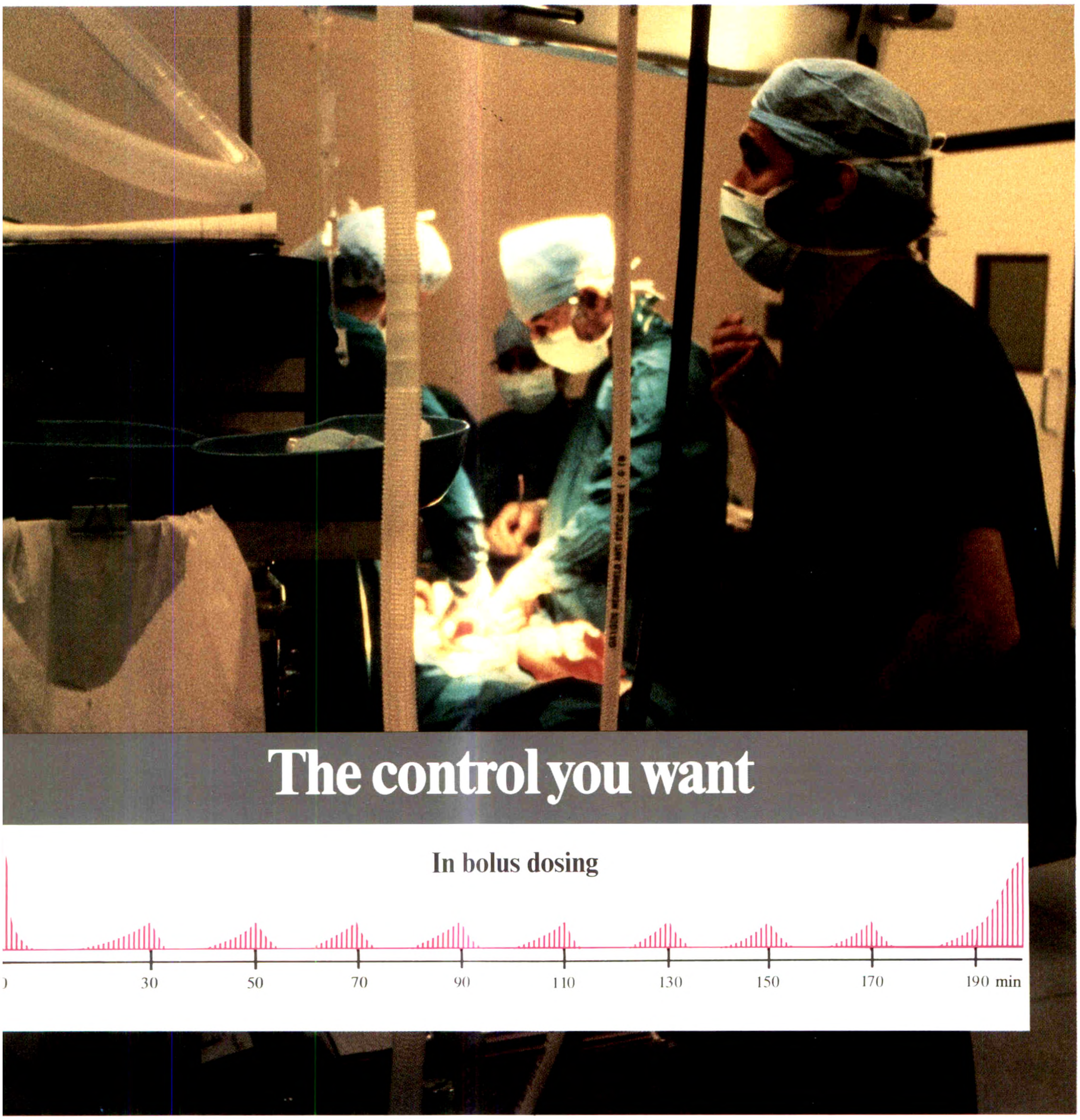

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Editorial

Chirality in anaesthesia

The term chirality literally means ‘having handedness’, and has been used in relation to molecular structure for approximately 100 years. Our right and left hands are mirror images of each other, but cannot be superimposed on each other when the palms are facing the same direction. Similarly, many drugs can exist as right- and left-handed forms that are nonsuperimposable mirror images of each other; these two forms are known as R and S isomers (from the Latin words rectus and sinister). The R and S isomers of drugs are also known as enantiomers (i.e. substances of opposite shape). They have identical physical and chemical properties, but rotate polarised light in opposite directions; consequently, they are commonly referred to as optical isomers, and defined by the direction of optical rotation, using the prefixes (+) and (−), or (d) and (l). Equal mixtures of the two forms (racemic mixtures, with the prefixes (±) or (dl)) have no optical activity [1].

This type of stereo-isomerism is dependent on the presence of a centre of molecular asymmetry in the chemical structure of a drug; this centre is usually a carbon atom with four different atoms or groups attached to it. Drugs with this type of structure (chiral drugs) have a mirror-image that cannot be superimposed upon their original configuration, and can therefore exist as R and S isomers that are optically active [2].

Some chiral drugs are administered as single, pure, isomers. For example, many naturally occurring compounds (e.g. drugs derived from plants or synthesised by organisms) contain one or more centres of molecular asymmetry. However, their formation is usually stereo-selective, so they are synthesised and administered as single, specific isomers (e.g. l-morphine, l-hyoscine, and d-tubocurarine). Atropine is an exception; although present in solanaceous plants as an l-isomer, it is partly converted to its enantiomer during extraction, and is administered as a racemic mixture (dl-hyoscyamine). During this process, its anticholinergic activity is reduced by approximately 50%, since the d-isomer has little or no effect. Nevertheless, almost all naturally occurring drugs are administered as single isomer preparations.

In contrast, synthetic chiral drugs that are used in medicine are usually prepared as equal, racemic mixtures of R and S enantiomers. The R and S isomers have the same substituent groups, but they occupy different positions in space. Although most of their properties are identical, the R and S enantiomers may form different three-dimensional relationships in the asymmetric environment of receptors and enzymes; this may result in significant differences in their pharmacodynamic effects and their pharmacokinetic properties [3, 4]. These differences in biological activity are not surprising, since the individual enantiomers combine with receptors or enzymes consisting of chiral amino-acids (i.e. L-amino-acids) with stereo-selective properties. In some instances, one isomer is inactive or harmless (as in the case of atropine); alternatively, it may be responsible for unwanted or toxic effects. There may be differences in both the affinity and the intrinsic activity of the enantiomers. Occasionally, they may produce opposite responses (e.g. agonist and antagonist effects) on identical receptor systems, and this phenomenon may account for the partial agonist activity of racemic drugs. In addition, the pharmacokinetic processes of distribution, protein-binding, metabolism, and elimination may be stereo-selective, and differ with the two isomeric forms [4, 5]. For example, one chiral form may be more extensively metabolised, undergo chiral inversion to its enantiomer, or inhibit its metabolism. In these conditions, the determination of the plasma concentrations and pharmacokinetics of chiral mixtures may be extremely inaccurate and misleading, since it will not reflect the behaviour of the active enantiomer. Indeed, according to some, the generation of pharmacokinetic data on racemic mixtures that fail to distinguish between the enantiomers is little better than unscientific, sophisticated nonsense [3, 6]. In some circumstances, the administration of drugs as chiral mixtures is comparable with the use of two different agents.

More than half the synthetic agents commonly used in anaesthetic practice are chiral drugs. Almost all these synthetic chiral drugs are administered as racemic mixtures, rather than as single, pure enantiomers. In some instances, there are important differences between the individual stereoisomers.

For example, differences are present between the R and S isomers of all chiral intravenous anaesthetics. Thus, etomidate is used as the R(+)-isomer; its S(−)-enantiomer has only slight sedative and hypnotic activity. Similarly, there are significant differences between the pharmacokinetics and pharmacodynamics of many barbiturate derivatives; in general, the S(−)-isomers are more potent but have shorter terminal half-lives [7]. Methohexitone possesses two chiral centres, and thus can exist as four stereo-isomers (as well as two racemic mixtures). In animal studies, one of these isomers was up to five times more potent than the others [8]. The drug was originally used clinically as a mixture of all four isomers, but produced an unacceptable degree of excitatory effects. For the past 30 years, methohexitone has been used as a racemic mixture of the two less excitatory isomers. Similarly, thiopentone is administered as a racemic mixture; the S(−)-isomer is more potent, but has a shorter half-life than its R(+)-enantiomer [9]. These differences are also present in the stereoisomers of its metabolite pentobarbitone, which is at least partially responsible for the prolonged after-effects of thiopentone anaesthesia.

Ketamine provides a further example of the effects of chirality on the action of anaesthetics. The evidence is mainly derived from a clinical study in which the effects of racemic ketamine, R(−)-ketamine, and S(+)-ketamine were compared in a double-blind study in three groups of unpremedicated outpatients undergoing elective surgical procedures [10]. S(+)-ketamine was approximately three times as potent as R(-)-ketamine, and produced adequate anaesthesia in a higher proportion of patients. In addition, the S(+) enantiomer caused significantly less psychotic emergence reactions, agitated behaviour, and postoperative pain, and better intra-operative amnesia. Although these results were slightly modified by subsequent studies [11], they suggest that ketamine would be a more useful drug (and indeed, a more frequently used drug) if it was available as the S(+) isomer, rather than as a racemic mixture. Studies of this type provide an important insight into

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the nature of intravenous anaesthesia; they strongly suggest that hypnotic effects are due to an effect on chiral receptors or enzymes in the CNS, rather than to physicochemical or nonspecific actions.

Many fluorinated inhalational anaesthetics are also chiral drugs. Thus, halothane, enflurane, and isoflurane contain a centre of molecular asymmetry, and can exist as R and S isomers [1, 7]. Presumably, the drugs that are used clinically are chiral mixtures of the two enantiomers (although little or nothing is known about them or their activity). Their investigation might provide an invaluable insight into the nature of general anaesthesia; similarly, studies of the stereo-selective metabolism of halothane might be of significant practical importance.

Many amide local anaesthetics (i.e. mepivacaine, prilocaine, and bupivacaine) are chiral, and are used clinically as racemic mixtures. Although their R and S enantiomers have approximately equal activity, there are important differences between them. S(+)-prilocaine, S(+)-mepivacaine, and S(−)-bupivacaine have a longer duration of action than their R-enantiomers, due to enhanced vasoconstriction [12]. In addition, R(−)-prilocaine is more rapidly metabolised than its S(+)-enantiomer; in experimental conditions, plasma concentrations of both *o*-toluidine and methaemoglobin are higher [13]. In some conditions, there are also differences in the toxicity of the stereo-isomers. Indeed, recent electrophysiological studies suggest that the cardiotoxicity of bupivacaine is predominantly due to the R(+)-isomer [14]. Thus, local anaesthetic enantiomers with the S-configuration appear to have considerable advantages; it is therefore unsurprising that an amide anaesthetic under current development (ropivacaine) will only be available as the S-isomer. (It should, perhaps, be pointed out that many of the potential advantages of ropivacaine are also possessed by S(−)-bupivacaine.)

Other drugs used in anaesthetic practice are also administered as chiral mixtures. Atracurium, for example, is a complex mixture of 10 stereo-isomers with different pharmacological properties [15]. Dobutamine is a racemic mixture of two enantiomers, both of which play a role in the relatively selective inotropic effects of the drug. R(+)-dobutamine acts on beta$_1$ and beta$_2$ receptors; in contrast, S(−)-dobutamine is a potent agonist at postsynaptic myocardial alpha$_1$ adrenoceptors [16]. Almost uniquely, the combination of both isomers is essential for its clinical effectiveness.

Until recently, the use of most synthetic drugs as chiral mixtures has been accepted uncritically, since the expense involved in the separation of stereo-isomers on an industrial scale has been extremely high. During the past decade, progress in chemical technology has greatly simplified the separation and the preparation of individual stereo-isomers (e.g. by specific chiral synthesis or by chiral inversion of one enantiomer). Separation of the stereo-isomers of chiral mixtures has a long and distinguished history; in 1848, Louis Pasteur successfully separated two sets of enantiomorphic crystals from sodium ammonium racemate by hand (hence the origin of the words racemic and racemate). Should, perhaps, all synthetic anaesthetic drugs be administered as the single most active and safest enantiomer rather than as chiral mixtures? In some instances (notably ketamine and some local anaesthetics), this would have definite, practical, clinical advantages. In other cases, the advantages are less clear. In some countries, drug regulatory authorities may therefore continue to allow the development and use of drugs as chiral mixtures. However, in the 1990s there are surely very few arguments for administering synthetic drugs as chiral mixtures when the technology exists for their preparation as single, pure, and specific stereo-isomers.

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Anaesthesia, 1992, Volume 47, pages 95–100

Upper oesophageal sphincter pressure and the effect of cricoid pressure

R. G. VANNER, J. P. O'DWYER, B. J. PRYLE AND F. REYNOLDS

Summary

Upper oesophageal sphincter pressure has been measured in 24 patients with a sleeve device. The median sphincter pressure when awake was 38 mmHg, and when anaesthetised and paralysed was 6 mmHg. After tracheal intubation, cricoid pressure was applied at measured values between 5 and 50 N using a hand-held cricoid yoke while the sphincter pressure was recorded in two head and neck positions: with and without a standard intubating pillow with neck support. A cricoid force of 40 N increased sphincter pressure to above 38 mmHg in all the patients and the use of the pillow did not alter this effect. With the application of cricoid pressure, operating department assistants raised sphincter pressure to above 38 mmHg in only 50% of patients. Laryngoscopy made little difference to the effect of cricoid pressure except in one patient in whom it reduced the sphincter pressure by 27 mmHg.

Key words

Anatomy; cricopharyngeus.
Complications; aspiration.
Larynx; cricoid pressure.

The upper oesophageal sphincter is formed mainly by cricopharyngeus, a striated muscle situated behind the cricoid cartilage. The muscle tone of cricopharyngeus creates a sphincter pressure which prevents regurgitation in the awake state [1]. Neuromuscular blocking drugs have been shown to cause a marked reduction of sphincter pressure in the opossum [2] and in humans [3] but in the latter case it was not quantified. Cricoid pressure is designed to counteract this reduction in upper oesophageal sphincter pressure (UOSP) and prevent the regurgitation of oesophageal contents into the pharynx in the period between induction of anaesthesia and the insertion of a tracheal tube.

Sellick described the technique of cricoid pressure in which the head and neck were positioned without a pillow as in the position for tonsillectomy [4]. The anterior convexity of the cervical spine in this position may aid oesophageal occlusion but can make laryngoscopy difficult [5,6]. The ideal intubating position with a pillow beneath the occiput was described by Magill [7] and most anaesthetists now use this position during tracheal intubation with cricoid pressure [8–12]. The average height of the pillow in the ideal position has since been defined as 5.5 cm [13]. Neck support has been recommended to prevent the head flexing on the neck during cricoid pressure, either by the use of a bimanual technique [14] or with a cuboid of foam rubber [15].

In the present study a manometry catheter with a sleeve device was used to measure continuous UOSP in patients while awake, anaesthetised and paralysed and to assess the effect of cricoid pressure on UOSP and whether it is altered by a pillow.

Method

Measurement of UOSP

A Dent sleeve is a 4.0 mm diameter manometry catheter with a 6 cm sleeve on one side which, when perfused with water through a transducer, performs as a Starling resistor measuring the highest pressure along the length of the sleeve [16]. If the rate of perfusion is 0.6 ml.min^{-1}, there is a 17 s response time to an increase in pressure [17]. When the sleeve is positioned so that it faces posteriorly in the upper oesophageal sphincter it can measure sphincter pressure continuously [18]. Positioning the catheter was helped by measuring pressure through a side-hole at the distal end of the sleeve. The position of the upper oesophageal sphincter was first identified as a high pressure zone with the side-hole pressure reading, before advancing

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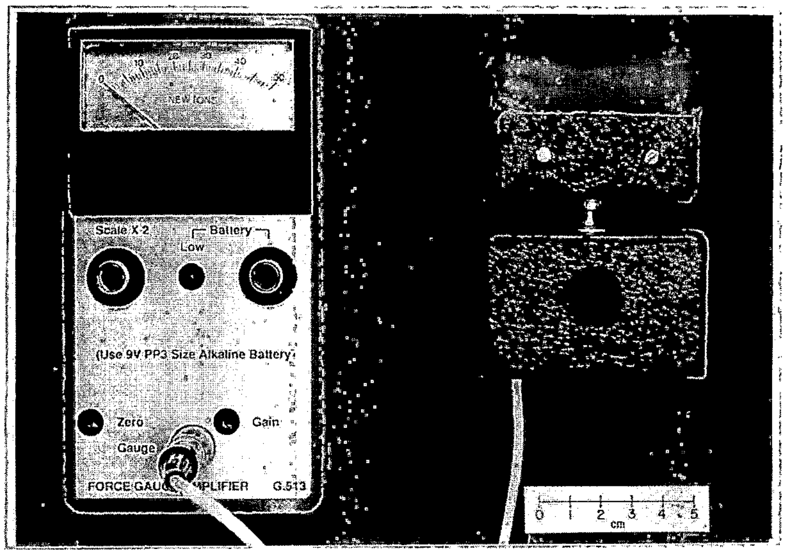

Fig. 1. The cricoid yoke, showing the foam pad, and the handle with load cell connected by wire to the amplifier box with display.

the catheter so that the sleeve straddled the sphincter. The catheter was then turned until the sleeve faced posteriorly. The sleeve was perfused with water through a low compliance system at 0.6 ml.min^{-1} and the side-hole at 0.2 ml.min^{-1}. Pressures were measured by two calibrated transducers with both a digital and a screen display (Diascope 2, S & W Vickers). The catheter was zeroed before insertion to a level behind the cricoid cartilage and was checked after removal.

Measurement of cricoid pressure

A hand-held cricoid yoke with a shaped foam pad (Fig. 1) was used to apply cricoid pressure. The applied force was measured by a load cell in the handle and applied force displayed in Newtons (N) on a gauge. The cricoid yoke was zeroed and then calibrated on weighing scales before each use (1 kg = 9.81 N).

The standard pillow

The standard pillow was made of 6-cm deep firm foam rubber with an integral firm neck support 4 cm above this height. The neck support was designed to prevent the head flexing on the neck during cricoid pressure without causing hyperextension of the neck. When the pillow was removed a standard 5 cm firm neck support was used.

Hospital ethics committee approval was granted for the study and informed consent was obtained from adult patients, ASA 1 and 2, who were scheduled to require tracheal intubation and muscle relaxation during anaesthesia for elective surgery. One hour after premedication with intramuscular papaveretum (mean dose 0.18 mg.kg^{-1}) and hyoscine, and shortly before surgery, the patient swallowed the manometry catheter via an anaesthetised nostril. The UOSP while awake was measured after 2 min when the patient had settled on the pillow. After the induction of anaesthesia and muscle relaxation with suxamethonium 1.0 mg.kg^{-1}, but before tracheal intubation, baseline UOSP was measured together with one measurement of UOSP with cricoid pressure at 20 N. The trachea was intubated with a standard pvc tube, size 8 mm internal diameter for women and 9 mm for men. At least 8 min later, after administration of vecuronium 0.1 mg.kg^{-1}, UOSP was measured during the application of cricoid pressure in the two positions: one with the standard pillow and the other with the standard neck support only. Cricoid pressure was applied by one operator (R.V.) using the cricoid yoke at measured values between 5 and 50 N. While applying 20 N of cricoid force with the pillow in position, laryngoscopy was performed and any alteration in UOSP was noted. The operating department assistants, who were all trained and regularly performed cricoid pressure in the clinical situation, then applied cricoid pressure (without the Yoke) and UOSP was recorded with and without the pillow.

Statistical analysis

The Wilcoxon matched-pairs signed-rank test was used to compare the UOSP values in the two positions with cricoid pressure. (Paired *t*-test on the $\log_{10}$ data was also applied

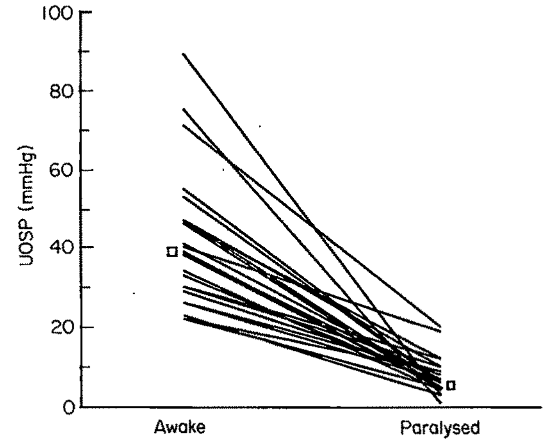

Fig. 2. Upper oesophageal sphincter pressure (UOSP) awake and after anaesthesia and neuromuscular blockade in each patient. The square symbols represent the median values.

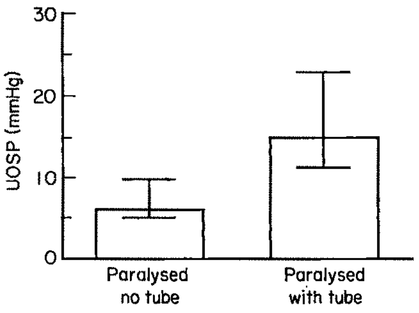

Fig. 3. The effect of the tracheal tube on upper oesophageal sphincter pressure (UOSP) in the anaesthetised paralysed patient. Median values are shown and the vertical bars indicate the 75th and 25th percentiles.

and gave the same level of significance.) The Wilcoxon matched-pairs signed-rank test was also used to assess the effect of laryngoscopy on UOSP values with 20 N of cricoid force. The Mann–Whitney *U*-test was used to compare UOSP values between male and female patients.

Results

A total of 26 patients were recruited, but two were not studied because of problems with the pressure measuring equipment. Twenty-four patients, (12 men and 12 women) were studied; their mean age was 47 (range 33–64) years. The values of UOSP were not normally distributed but had a positive skew. The median, 25th and 75th percentiles are therefore presented. The median UOSP in awake patients was 38 mmHg and with anaesthesia and muscle relaxation without the tracheal tube was 6 mmHg (Fig. 2). The presence of the tracheal tube caused a rise in UOSP (Fig. 3). In each patient the rise in UOSP after intubation was subtracted from the UOSP values produced by cricoid pressure as this is performed without a tracheal tube in the clinical situation. The UOSP values with 20 N of cricoid force before insertion of the tracheal tube are similar to the corrected values when 20 N was used after insertion of the tracheal tube (Fig. 4).

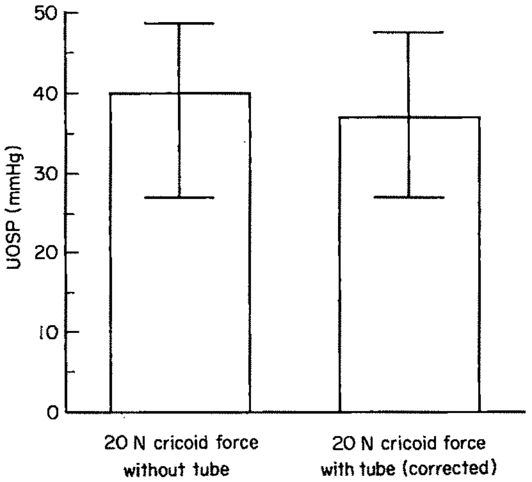

Fig. 4. The upper oesophageal sphincter pressure (UOSP) with 20 N of cricoid force before and after tracheal intubation. (In the latter case the contribution from the tube is subtracted.) Median values are shown and the vertical bars indicate the 75th and 25th percentiles.

When the pillow was removed the level of the zero point fell by 3.0 cm, so 2.0 mmHg was added to these results. In all individuals and in both positions, UOSP rose with increasing cricoid force, but varied widely between patients particularly at high levels of cricoid force (Fig. 5). UOSP

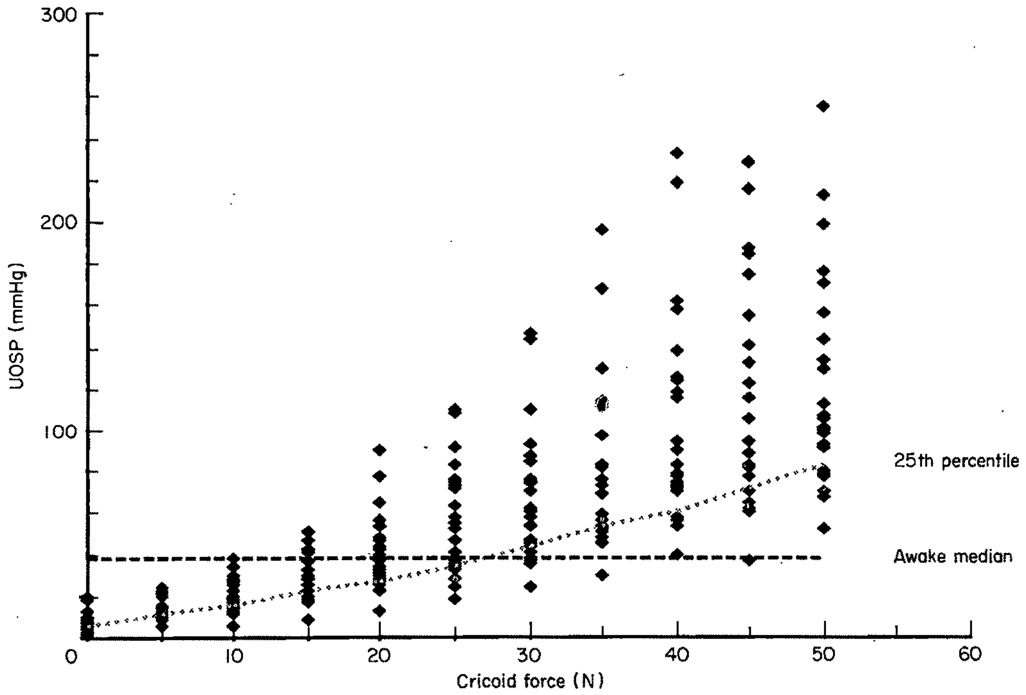

Fig. 5. A scatter diagram showing all the measurements of upper oesophageal sphincter pressure (UOSP) with increasing values of cricoid pressure with the patients positioned on the pillow. The measurements with the same value have not been separated and are represented by only one symbol. The 25th percentile of these measurements is drawn as a dotted line: ...... The median of the awake values of UOSP is indicated by a horizontal dashed line: ------ for comparison.

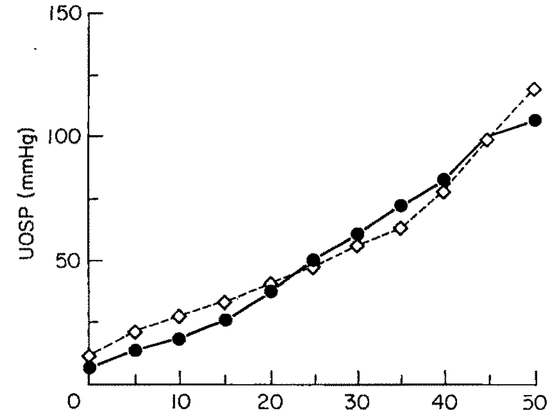

Fig. 6. The median measurements of upper oesophageal sphincter pressure (UOSP) with increasing values of cricoid pressure in the two positions. Solid line: with the pillow. Dashed line: without the pillow.

was significantly higher ($p < 0.01$) without the pillow at 0, 5, 10, and 15 N of cricoid force. There was no significant difference ($p > 0.05$) at any other cricoid force (Fig. 6). The UOSP achieved by the operating department assistants during circoid pressure is shown in Figure 7 and there was no significant difference ($p > 0.05$) in the two positions. Laryngoscopy reduced the UOSP generated by 20 N of cricoid force in 17 out of 23 patients. This reduction was slight and not statistically significant ($p > 0.05$), but in one patient laryngoscopy reduced UOSP from 39 mmHg to 12 mmHg (Fig. 8). There was no significant difference ($p > 0.05$) in UOSP between male and female patients with any values of applied cricoid force. There was no correlation between UOSP produced by crocoid pressure and the patient's age, weight or UOSP value when awake.

Discussion

In normal subjects, gastric distension causes a reflex relaxation of the lower oesophageal sphincter, allowing spontaneous gastro-oesophageal reflux [19,20]. During spontaneous reflux, oesophageal pressure can rise by 5–10 mmHg when the lower oesophageal sphincter relaxes and oesophageal pressure equals gastric pressure with the development of a common cavity [19]. However, regurgitation does not normally occur because the pharynx is protected by the upper oesophageal sphincter. The present work has shown that anaesthesia with muscle relaxation lowers UOSP to about 6 mmHg, a level that will allow the regurgitation of oesophageal contents into the pharynx in most patients. The UOSP that will prevent passive regurgitation in all patients is not known. If the patient has not regurgitated when awake, maintaining this awake value for UOSP by the application of cricoid pressure should prevent regurgitation during the induction of general anaesthesia. The median awake UOSP of 38 mmHg was exceeded in 75% of the patients by a cricoid pressure of 30 N and in all patients by a cricoid pressure of 40 N (Fig. 5). Although cricoid pressure of up to 15 N generated a significantly higher UOSP without a pillow, the pillow made no difference to the UOSP at the high levels of cricoid pressure necessary to prevent regurgitation.

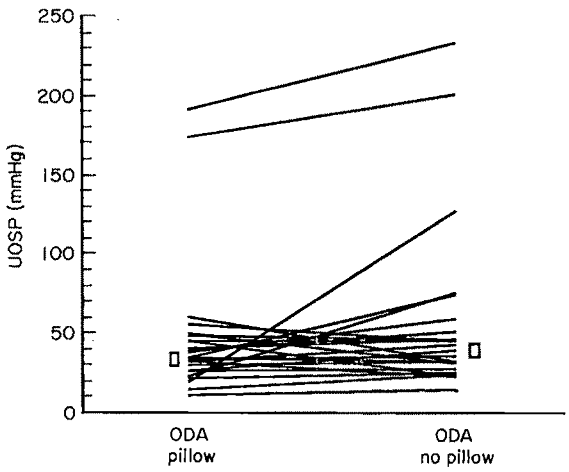

Fig. 7. The upper oesophageal sphincter pressure (UOSP) achieved with cricoid pressure by each operating department assistant (ODA) with the patient in two positions: with and without the pillow. The square symbols represent the median values.

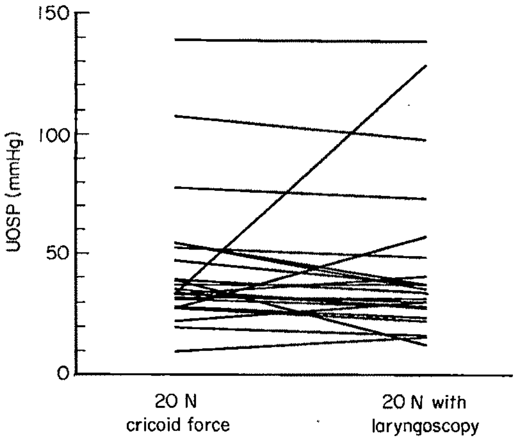

Fig. 8. The upper oesophageal sphincter pressure (UOSP) with 20 N of cricoid force and the effect of laryngoscopy.

In a recent study [21] of 14 conscious subjects in whom UOSP was measured continuously while lying supine for 2 h after a meal, there were 28 episodes of spontaneous regurgitation as indicated by a fall in pharyngeal pH. The UOSP during regurgitation was 10–25 mmHg and when the UOSP was greater than 25 mmHg there was no regurgitation. A high gastric pressure may raise oesophageal pressure during gastro-oesophageal reflux with the development of a common cavity. Two studies have demonstrated a high gastric pressure in the supine position in starved patients: one of 20 conscious women in the last trimester of pregnancy had a gastric pressure of 25 mmHg [22], and one of 27 anaesthetised patients during suxamethonium fasciculations also had a gastric pressure of 25 mmHg [23]. Gastric pressure has not been recorded with a full stomach. However, the stomach is compliant and Holloway *et al.* showed in 33 patients that the inflation of a 750 ml balloon in the stomach usually raised gastric pressure by 2–6 mmHg but occasionally up to 10 mmHg [20]. These observations all suggest that a gastric pressure when supine at rest would be unlikely to exceed 35 mmHg, and UOSP of over 35 mmHg should prevent passive regurgitation.

An *in-vitro* study [24] has shown that pvc tracheal tubes at 21°C would generate a posterior force of 4.5 N on the larynx when conforming to the S-shape of the airway [25].

This would explain our finding that the tracheal tube increased the UOSP by an average of 10 mmHg with the patients on the pillow. We did not measure the UOSP before intubation without the pillow; it is possible that the higher UOSP at 0, 5, 10, and 15 N of cricoid force without a pillow may have been due to a greater contribution from the tracheal tube in this position [25].

Cricoid pressure in the clinical situation is normally applied without a tracheal tube. All but one of our measurements with cricoid pressure were taken with the tracheal tube in place. (This was essential to secure the airway during a procedure which normally took 15 min.) However, as the UOSP values with 20 N of cricoid force before insertion of the tracheal tube were similar to the corrected values after intubation, we believe that our results are still relevant to the clinical situation. Using a different methodology, but with a pillow beneath the occiput, previous workers have shown that a cricoid force of 44 N raised UOSP to 55 mmHg in 50% of their patients and to above 32 mmHg in all of them, and they also had a wide distribution of data [26]. Their mean baseline UOSP without cricoid pressure was much higher at 34 mmHg, however, they made no correction for the presence of the tracheal tube and a third of their patients were not paralysed. 'Pharyngeal pressure' has previously been measured during anaesthesia with muscle relaxation but again the mean value of 23 mmHg was higher than ours due to the contribution from the tracheal tube [27]. No previous studies have measured true baseline UOSP after muscle relaxation in humans.

When the operating department assistants applied cricoid pressure to patients on the pillow 50% produced a UOSP pressure of less than 38 mmHg, and in 25% the UOSP was less than 25 mmHg. Up to half of the patients would have been at risk of regurgitation during cricoid pressure had they had high gastric pressures and gastro-oesophageal reflux. These results can be compared to the performance of 10 trained operating department personnel when applying cricoid pressure to a test rig in which half of them generated less than 40 N [28]. To improve their performance, a set of weighing scales set at 4 kg may be useful for training purposes. A cricoid yoke could be used, but Lawes *et al.* found a 7% incidence of laryngeal distortion and difficult intubation when 44 N was applied, using a cricoid yoke during the induction of anaesthesia for Caesarean section [29]. Our cricoid yoke has a continuous display of applied force which can be varied in a controlled manner in certain situations: increasing from 20 to 40 N with loss of consciousness, and decreasing from 40 to 30 N if laryngeal distortion hinders tracheal intubation.

The lumen of the upper oesophageal sphincter behind the cricoid cartilage is cresent-shaped [30] and the position of a manometry catheter may vary within the lumen between patients. This may explain our wide distribution of measured UOSP values with the positive skew; a catheter in the midline may be squeezed harder against the vertebral column and anterior vertebral muscles during cricoid pressure than a catheter in a more lateral position. The low pressure of a more laterally placed catheter is more likely to reflect the true oesophageal occlusion pressure. This may also explain why such an apparently large force is needed to prevent regurgitation with cricoid pressure.

Forty Newtons of cricoid force raised the UOSP to above the median of the awake values in all the patients, and would counteract the fall in UOSP on induction of anaesthesia and muscle relaxation. This effect was the same with and without the pillow. The use of a head and neck position similar to that provided by the standard intubating pillow described here does not negate the value of cricoid pressure.

Acknowledgments

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Anaesthesia, 1992, Volume 47, pages 101–104

A comparison of omeprazole and ranitidine for prophylaxis against aspiration pneumonitis in emergency Caesarean section

G. YAU, A. F. KAN, T. GIN AND T. E. OH

Summary

One hundred and sixty-two Chinese women undergoing emergency Caesarean section were allocated at random on admission to the labour ward to receive one of three regimens for orally administered chemoprophylaxis against acid aspiration: ranitidine 150 mg 6 hourly with sodium citrate at induction of anaesthesia, omeprazole 40 mg 12 hourly with sodium citrate, or omeprazole 40 mg 12 hourly alone. Intragastric pH and volume were measured immediately after induction of anaesthesia. Ten patients (17%) in the omeprazole-only group, three (6%) in the omeprazole and citrate group and one (2%) in the ranitidine group had an intragastric pH < 2.5 and volume > 25 ml ($p < 0.05$). The use of sodium citrate resulted in higher intragastric pH but larger intragastric volumes ($p < 0.05$). The sodium citrate and ranitidine regimen was the most cost-effective among the three.

Key words

Anaesthesia; obstetric.
Complications; aspiration.
Gastrointestinal tract; intragastric pH, volume.

Acid aspiration syndrome is still an important contributor towards anaesthetic-related deaths [1]. An intragastric pH < 2.5 with an intragastric volume > 25 ml was believed to place the patient at high risk of severe lung damage [2] although this has been questioned recently [3]. Numerous regimens have been used for chemoprophylaxis against acid aspiration in patients undergoing emergency Caesarean section [4, 5] but none consistently maintain intragastric pH > 2.5 with volumes < 25 ml. Ranitidine 6 hourly, with sodium citrate before induction of general anaesthesia, maintained gastric pH > 2.5, but gastric volumes were still considerable [6–8].

Omeprazole is a new drug which inhibits gastric acid production by selectively blocking the proton pump in gastric parietal cells [9]. It was more effective than ranitidine at maintaining pH > 3.5 in women for elective Caesarean section, without the use of sodium citrate, and all volumes were less than 25 ml [10]. An omeprazole regimen for patients in active labour may minimise the problem of large intragastric volumes. This study compared the effects of omeprazole 40 mg given 12 hourly, and ranitidine 150 mg given 6 hourly, during labour, on gastric pH and volume in patients undergoing emergency Caesarean section.

Methods

The protocol was approved by the Research Ethics Committee of the Chinese University Faculty of Medicine and informed consent was obtained from all patients. All patients on admission to the labour ward were assigned at random on a daily basis to receive one of the following regimens: group 1, ranitidine 150 mg orally 6 hourly, 30 ml 0.3M sodium citrate orally 15 min before induction of anaesthesia, group 2, omeprazole 40 mg orally 12 hourly, 30 ml 0.3M sodium citrate orally 15 min before induction of anaesthesia, group 3, omeprazole 40 mg orally 12 hourly, no sodium citrate. All patients were fasted from the time of admission to the labour ward, and the time of last oral intake was noted. Patients who required urgent Caesarean section within 30 min of admission to the labour ward were not studied.

For Caesarean section, all women were placed in the left lateral tilt position and monitored with ECG, pulse oximetry and noninvasive arterial pressure (Dinamap 18465X Critikon Inc, Tampa, Fl, USA). Following pre-oxygenation for 3 min anaesthesia was induced with thiopentone $4\ \mathrm{mg.kg^{-1}}$ while cricoid pressure was applied. After loss of the eyelash reflex, suxamethonium

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1.5 mg.kg^{-1} was given to facilitate tracheal intubation. Anaesthesia was maintained with nitrous oxide 50% and enflurane 1% in oxygen. Atracurium 0.5 mg.kg^{-1} was given and ventilation controlled to maintain the end-tidal carbon dioxide concentration between 4.0 and 4.5 kPa. At delivery, oxytocin 10 units and morphine 0.2 mg.kg^{-1} were given. The nitrous oxide was increased to 70%, enflurane was reduced to 0.5%, and eventually discontinued at the start of skin closure. Atropine 1.2 mg and neostigmine 2.5 mg were given to antagonise residual neuromuscular block.

Gastric aspiration was performed after induction of anaesthesia using a 16-FG Salem sump tube (Sherwood Medical, St. Louis, MO.63103, USA) which was inserted orally after tracheal intubation. The Salem sump tube was advanced until the third 10 cm marking was at the lips, and correct positioning checked by auscultation of injected air. Aspiration was performed with a 50 ml syringe and repeated after the tube was withdrawn and re-advanced first 10 cm and then 20 cm. Volumes were measured directly from the 50 ml syringe which was graduated in 1 ml markings. Measurements of pH were made using a Corning 240 pH meter (Corning, NY, USA) and also using Millipore pH paper.

The pH meter was calibrated daily at pH 4 and 7. All pH measurements were made by an investigator who was unaware of which drug the patient had been given. All infants were examined by a neonatologist and Apgar scores at 1 and 5 min, and birth weight, were recorded.

Demographic data were compared among groups using analysis of variance. The times from last oral intake to time of aspiration (fasting time), time from start of drug treatment to time of gastric aspiration (treatment time), intragastric pH and intragastric volumes were compared among groups using the Kruskal–Wallis test. The incidence of treatment failures, defined as the number of patients with gastric pH < 2.5 and volume > 25 ml, was compared using Fishers Exact test. Further analysis was performed on subgroups of the data, including those patients who had received pethidine and groups whose treatment times were less than 6 or 12 h. Kendall rank correlation was used to compare fasting times and treatment times with gastric volume and pH. A $p < 0.05$ was considered significant.

Results

A total of 162 patients were studied (49 ranitidine and sodium citrate, 53 omeprazole and sodium citrate, 60 omeprazole alone). There were no differences in age, weight, height or parity among the three groups. The fasting time was longer in the ranitidine group compared with the omeprazole and citrate group (Table 1, $p < 0.05$). The duration of treatment was longer in the omeprazole group compared with the ranitidine group (Table 1, $p < 0.05$).

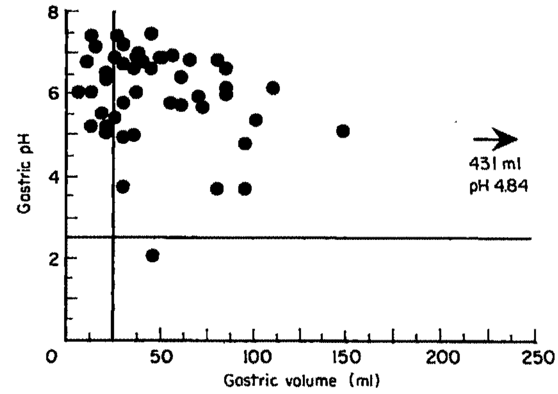

Fig. 1. Intragastric pH and volume in patients after 150 mg ranitidine and 30 ml sodium citrate.

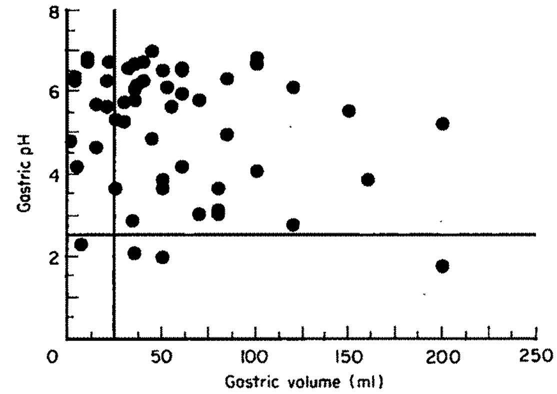

Fig. 2. Intragastric pH and volume in patients after 40 mg omeprazole and 30 ml sodium citrate.

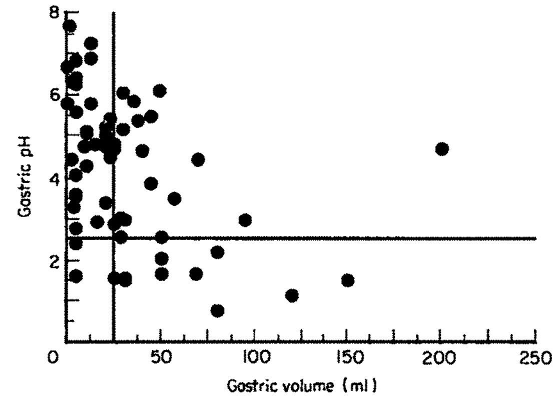

Fig. 3. Intragastric pH and volume in patients after 40 mg omeprazole.

There was one patient in the omeprazole group who had no gastric aspirate and pH could not be estimated. Plots of intragastric pH values against intragastric volumes are shown in Figures 1 to 3. By the criteria of Roberts and Shirley [2], patients falling into the quadrant with pH less

Table 1. Median (range) fasting times and treatment times.

Group		Fasting time (h)	Treatment time (h)
Ranitidine+citrate	($n = 49$)	11.0 (2.7–31.3)	5.5 (1.5–15.4)
Omeprazole+citrate	($n = 53$)	9.0 (1.0–19.5)*	6.1 (0.5–18.5)
Omeprazole	($n = 60$)	10.6 (1.5–30.0)	7.0 (1.0–20.0)*

*$p < 0.05$ compared with ranitidine group.

Table 2. Median (range) intragastric pH and volume.

Group	meter pH	paper pH	volume (ml)
Ranitidine+citrate	6.16 (2.11–7.50)	6.7 (2.0–7.7)	38 (6–431)
Omeprazole+citrate	5.67 (1.78–6.99)**	6.1 (2.0–7.4)**	45 (1–200)
Omeprazole	4.44 (0.81–7.28)*	4.8 (2.0–7.7)*	23 (0–200)*

*$p < 0.01$ compared with other groups, **$p < 0.01$ compared with ranitidine group.

than 2.5 and volume exceeding 25 ml are considered to be at maximum risk.

Group 1, ranitidine and sodium citrate

Patients in this group had a median intragastric volume of 38 ml and pH of 6.16 (Table 2). There was only one patient in the high risk quadrant with a volume of 48 ml and pH of 2.17 (Fig. 1). One patient in this group had a volume of 431 ml with a pH of 4.84. She had eaten some rice soup only 2 h prior to admission.

Group 2, omeprazole and sodium citrate

Patients in this group had a median intragastric volume of 45 ml and pH of 5.67 (Table 2). There were three patients with a pH < 2.5 and volume > 25 ml (Fig. 2).

Group 3, omeprazole only

Patients in this group had a median intragastric volume of 23 ml and pH of 4.44 (Table 2). There were 10 patients in the high risk quadrant (Fig. 3).

Intragastric pH was not correlated to fasting time or treatment time (Figs 4–6). There was a wide scatter of pH in those patients taking omeprazole alone (Fig. 6) whereas those patients taking ranitidine and sodium citrate had pH above 'at risk' level when the 'drug to aspiration' time exceeded two hours (Fig. 4).

The omeprazole-only group had lower pH than the other two groups (Table 2, $p < 0.01$). Patients who received omeprazole with citrate had more acidic pH than those who received ranitidine (Table 2, $p < 0.01$) although the difference between groups was only 0.5 pH unit. Patients in the two groups who received sodium citrate had larger intragastric volumes compared with the omeprazole-only group (Table 2, $p < 0.01$).

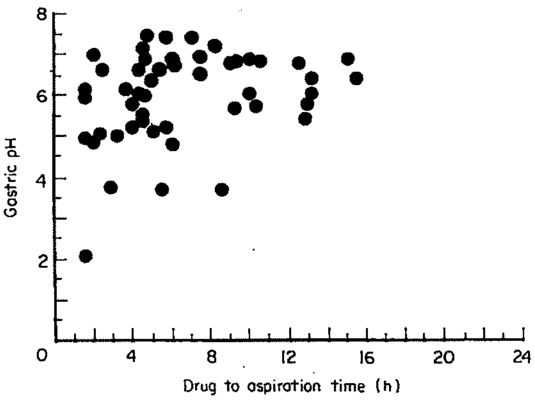

Fig. 4. Intragastric pH and time after medication (150 mg ranitidine and 30 ml sodium citrate).

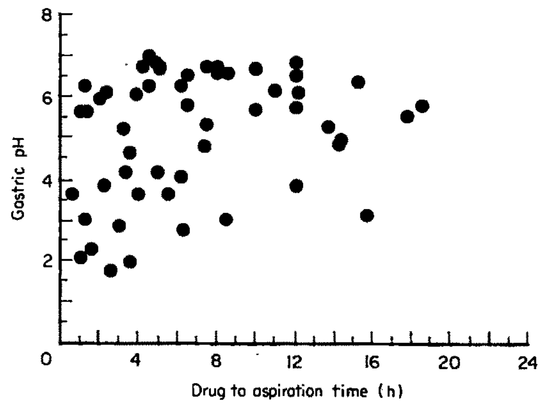

Fig. 5. Intragastric pH and time after medication (40 mg omeprazole and 30 ml sodium citrate).

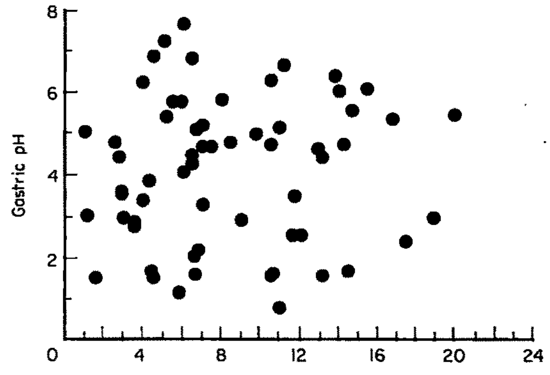

Fig. 6. Intragastric pH and time after medication (40 mg omeprazole).

There was no difference among the groups in the number of patients who received pethidine for pain relief during labour (25% overall). There were no differences in gastric pH or volume between those patients that received pethidine and those that did not.

There were no differences in neonatal Apgar scores between the groups.

Discussion

In addition to fasting patients in active labour, most obstetric centres in the United Kingdom carry out some form of chemoprophylaxis against acid aspiration syndrome [4]. The combination of H_2 receptor blocker and sodium citrate appears to be the yardstick against which other regimens are measured [4]. However, regimens involving the use of sodium citrate have produced mean intragastric volumes from 43 to 70 ml [7, 8]. Reducing the volume of sodium citrate from 30 ml resulted in lower mean intragastric volumes but intragastric pH was not consistently above 2.5 [8]. Ranitidine alone, orally or intramuscular, gave lower mean intragastric volumes but failed to maintain intragastric pH > 2.5 and volumes < 25 ml consistently [8, 11].

Two doses of omeprazole 40 mg were shown to be superior to two doses of ranitidine 150 mg in maintaining intragastric pH above 3.5 in patients undergoing elective Caesarean section and all volumes were less than 25 ml [10]. The present study, however, showed that the same regimen was not effective during labour. Forty-seven patients in the omeprazole-only group received just one 40 mg dose of omeprazole and this may be considered inadequate but even a single 80 mg dose has not been shown to be totally effective [12]. Thirteen patients in the omeprazole-only group received a second dose of 40 mg omeprazole and three still had an intragastric pH below 2.5. It is likely that omeprazole would be more effective when given more frequently and in higher dosage. However, omeprazole 40 mg is approximately three times more expensive than ranitidine 150 mg so that omeprazole does not become cost-effective, especially when it does not give superior results to ranitidine. These findings support the reservations that some workers have expressed on the value of omeprazole [14]. Omeprazole is also inactivated by gastric acidity [9], and the large intragastric volumes and possible delays in gastric emptying during labour [13] may have resulted in significant loss of efficacy. A delay in gastric emptying was reflected by the large intragastric volumes in all three groups.

The addition of sodium citrate to either omeprazole or ranitidine gave safer pH values when compared with omeprazole alone. This indicates that sodium citrate was important in maintaining intragastric pH above 'at risk' levels but also contributes to larger intragastric volumes. Is it acceptable for intragastric volume to exceed 25 ml in order to maintain intragastric pH consistently above 'at risk' levels? Recent work suggests that a much larger intragastric volume is necessary before there is sufficient gastro-oesophageal reflux to cause 25 ml of pulmonary aspirate [15]. The problem of large intragastric volumes in women during active labour is difficult to overcome. This appears to be a particular problem in this part of the world where patients usually eat a meal just before they come into hospital. We would recommend the routine insertion of orogastric tubes following induction of anaesthesia to empty the stomach. There is currently no regimen which consistently maintains pH and volume at acceptable levels so that the most critical factors in the prevention of acid aspiration syndrome remain good anaesthetic technique and correctly applied cricoid pressure.

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Anaesthesia, 1992, Volume 47, pages 105–106

Pipecuronium versus high dose vecuronium

I. A comparison of speed of onset and cumulation during isoflurane anaesthesia

W. HARROP-GRIFFITHS, N. FAUVEL, M. PLUMLEY AND S. FELDMAN

Summary

The onset time and tendency to cumulation of pipecuronium and high-dose vecuronium were studied during nitrous oxide anaesthesia supplemented with isoflurane. Pipecuronium 0.06 mg.kg^{-1} had a similar duration of action to vecuronium 0.015 mg.kg^{-1} (42 vs 49 min). Patients who received vecuronium had a shorter onset time of neuromuscular blockade ($p < 0.01$). The use of pipecuronium was associated with marked cumulation.

Key words

Neuromuscular relaxants; pipecuronium, vecuronium.
Anaesthetics, volatile; isoflurane.

It has been suggested [1] that pipecuronium may be an ideal neuromuscular blocking agent for long operations in patients with cardiovascular disease, as it possesses a duration of action and potency similar to pancuronium [2] and a greater degree of haemodynamic stability [3]. Vecuronium has a shorter duration of action than pipecuronium when given in doses equipotent for the degree of neuromuscular block (i.e. similar multiples of ED_{50} or ED_{90}), but can be given safely in doses of up to 0.4 mg.kg^{-1} in order to prolong its duration of action [4–6]. The purpose of this study was to determine whether doses of pipecuronium and vecuronium that have similar initial durations of action show differences in onset time and tendency to cumulation.

Methods

Institutional ethics approval was obtained for the study. Thirty ASA physical status 1 or 2 patients scheduled for elective surgery gave informed written consent, and were admitted to the study. The surgical procedures comprised major abdominal surgery (11 patients) or joint replacement surgery (19 patients). The patients were allocated randomly into one of two groups, and received either pipecuronium or vecuronium. After premedication with papaveretum and hyoscine, anaesthesia was induced with a sleep dose of thiopentone and maintained with 33% oxygen in nitrous oxide supplemented with an inspired concentration of between 0.5 and 1% isoflurane. A Datex Relaxograph was used to monitor neuromuscular function, recording the response of the adductor pollicis muscle to supramaximal stimulation of the ulnar nerve. The Relaxograph was attached before induction, after which baseline values were established. After a period of stabilisation, patients were given either pipecuronium 0.06 mg.kg^{-1} or vecuronium 0.15 mg.kg^{-1}; these doses were estimated to have a similar initial duration of action. Onset time of neuromuscular blockade was taken as the time between the administration of the neuromuscular blocking agent and the time when the first 'twitch' of the train-of-four (T1) reached less than 5% of control. Tracheal intubation was performed at this time. Maintenance doses (one fifth of the initial dose) were given when T1 returned to 10% of control. Statistical analysis was performed using unpaired Student's *t*-tests.

Results

Demographic data are presented in Table 1. Mean onset time and duration of the initial dose of neuromuscular

Table 1. Mean (SD) age and weight.

	Study group	
	Pipecuronium	Vecuronium
Age; years	53.5 (13.1)	47.0 (16.5)
Weight; kg	64.5 (13.5)	62.8 (8.9)

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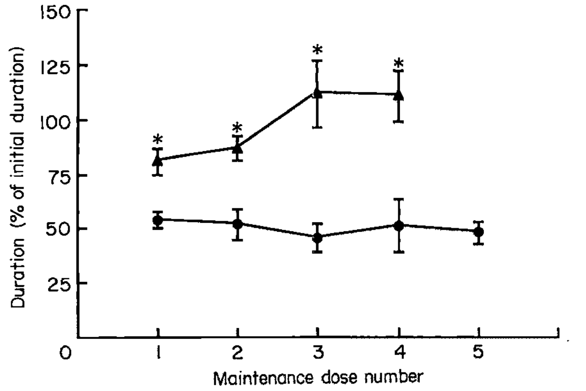

Fig. 1. Cumulation data: Mean durations of maintenance doses expressed as a percentage of duration of initial dose. Bars represent SEM. ▲, pipecuronium; ●, vecuronium ; *, significant difference between groups, $p < 0.05$.

blocking agent are shown in Table 2. There was a shorter mean onset time after vecuronium than after pipecuronium ($p < 0.01$). There was no statistically significant difference in mean duration of the initial dose between the pipecuronium and vecuronium groups. Figure 1 illustrates cumulation data. The durations of the first and subsequent maintenance doses for each patient were expressed as percentages of the duration of the initial dose. The numbers of patients from whom data were acquired for each data point in Figure 1 are given in Table 3. The mean percentage duration of the first and subsequent maintenance doses in the pipecuronium group were greater than those in the vecuronium group ($p < 0.05$). The pipecuronium group showed evidence of marked cumulation.

Discussion

Vecuronium has a more rapid onset than pipecuronium [1,4] when given in equipotent doses (i.e. similar multiples of ED_{90} dose). This, combined with our use of a $2 \times ED_{90}$ dose of pipecuronium and $4 \times ED_{90}$ dose of vecuronium in order to produce a similar duration of block, is likely to explain the markedly shorter onset time seen in the vecuronium group. The mean durations of the initial dose of pipecuronium and vecuronium were similar (42 and 49 min respectively). This would suggest that both agents, in the doses given, would prove suitable for providing surgical relaxation for a period of around 50 to 60 min. Isoflurane is known to potentiate the neuromuscular blocking effects of both vecuronium [7] and pipecuronium [8,9]. We conclude that both agents are suitable for providing muscle relaxation for long operations but that high-dose vecuronium may have advantages over pipecuronium in terms of a shorter onset time and a lesser tendency to cumulation if isoflurane is used as part of the anaesthetic technique.

Table 2. Mean (SD) onset time and duration of action of initial dose of neuromuscular blocking agent.

	Study group	
	Pipecuronium ($0.06\ mg.kg^{-1}$)	Vecuronium ($0.15\ mg.kg^{-1}$)
Onset time; min	3.28 (0.78)*	1.57 (0.50)
Duration; min	42.1 (12.2)	48.6 (10.8

* Significant difference beween groups ($p < 0.01$).

Table 3. Number of patients (*n*) from whom data were acquired for Figure 1.

	Study group	
	Pipecuronium *n*	Vecuronium *n*
Maintenance dose number		
1	9	9
2	8	4
3	8	4
4	6	3
5	—	3

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Anaesthesia, 1992, Volume 47, pages 107–109

Pipecuronium versus high dose vecuronium

II. A comparison of speed of onset and cumulation during propofol anaesthesia

W. HARROP-GRIFFITHS, M. PLATT, N. HIRSCH AND S. FELDMAN

Summary

The onset time and tendency to cumulation of pipecuronium and high-dose vecuronium were compared during nitrous oxide anaesthesia supplemented with a propofol infusion. Pipecuronium 0.06 mg.kg^{-1} had a similar duration of action to vecuronium 0.2 mg.kg^{-1} (49 vs 43). Patients who received vecuronium had a shorter onset time of neuromuscular blockade ($p < 0.01$). Neither pipecuronium nor vecuronium showed marked cumulation.

Key words

Neuromuscular, relaxants; pipecuronium, vecuronium.
Anaesthetics, intravenous; propofol

The introduction of propofol into clinical practice has rekindled interest in general anaesthesia that is supplemented by an intravenous rather than an inhalational agent. The current volatile agents all potentiate the effects of nondepolarising neuromuscular blocking agents; isoflurane appears to have the greatest effect [1–3]. The accompanying paper [4] reports that during an anaesthetic that included the use of isoflurane, doses of pipecuronium and vecuronium that have similar initial durations of action resulted in a more rapid onset of block with vecuronium and cumulation of effect after successive maintenance doses of pipecuronium. The aim of this trial was to study the onset time and tendency to cumulation of pipecuronium and high-dose vecuronium during nitrous oxide anaesthesia supplemented with a propofol infusion.

Methods

Institutional ethics approval was obtained. Informed written consent was given by 30 ASA 1 or 2 patients who were scheduled for elective surgery. The surgical procedures comprised craniotomy for clipping of aneurysm (12 patients) or for tumour resection (18 patients). The patients were allocated randomly to one of two groups of 15; one group received pipecuronium and the other vecuronium. No premedication was given. Anaesthesia was induced with a sleep dose of propofol and was maintained with 33% oxygen in nitrous oxide supplemented with a propofol infusion according to a scheme suggested by Roberts *et al.* [5]: 10 mg.kg^{-1} for the first 10 min, then 8 mg.kg^{-1} for the next 10 min and 6 mg.kg^{-1} thereafter, adjusted as necessary.

Fentanyl (0–4 µg.kg^{-1}) was given during anaesthesia to provide analgesia. A Datex Relaxograph was used to monitor neuromuscular function, recording the response of the adductor pollicis muscle to supramaximal stimulation of the ulnar nerve. The Relaxograph was attached before induction, after which baseline values were established. After a period of stabilisation, patients were given either pipecuronium 0.06 mg.kg^{-1} or vecuronium 0.2 mg.kg^{-1}. Onset time for neuromuscular blockade was taken as the time between the administration of the neuromuscular blocking agent and the time when the first 'twitch' of the train-of-four (T1) reached less than 5% of control. Intubation was performed at this time. Maintenance doses (one-fifth of the initial dose) were given when T1 returned to 10% of control. Statistical analysis was performed using unpaired Student's *t*-tests.

Results

Demographic data are presented in Table 1. Mean onset time and duration of the initial dose of neuromuscular blocking agent are shown in Table 2. There was a shorter

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Table 1. Mean (SD) age and weight.

	Study group	
	Pipecuronium	Vecuronium
Age; years	49.1 (14.1)	49.7 (14.6)
Weight; kg	71.3 (11.1)	70.3 (16.1)

Table 2. Mean (SD) onset time and duration of action of initial dose of neuromuscular blocking agent.

	Study group	
	Pipecuronium (0.06 mg.kg^{-1})	Vecuronium (0.2 mg.kg^{-1})
Onset time; min	3.97 (0.72)*	1.69 (0.38)
Duration; min	48.5 (25.1)	42.6 (8.5)

* Significant difference beween groups ($p < 0.01$).

Table 3. Number of patients (*n*) from whom data were acquired for Figure 1.

	Study group	
	Pipecuronium *n*	Vecuronium *n*
Maintenance dose number		
1	14	15
2	13	14
3	8	10
4	6	6
5	3	3

mean onset time after vecuronium than after pipecuronium ($p < 0.01$). There was no statistically significant difference in mean duration of the initial dose between the pipecuronium and vecuronium groups. Figure 1 illustrates cumulation data. The durations of the first and subsequent maintenance doses for each patient were expressed as percentages of the duration of the initial dose. The numbers of patients from whom data were acquired for each data point in Figure 1 are shown in Table 3. There were no statistically significant differences between the two groups in the durations of the first and subsequent maintenance doses. Neither group showed evidence of marked cumulation.

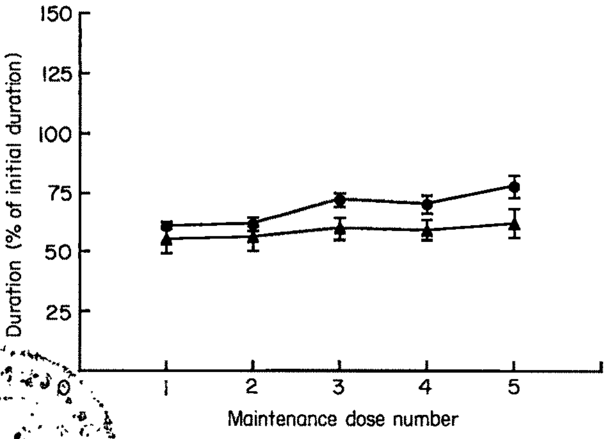

Fig. 1. Cumulation data: Mean durations of maintenance doses expressed as a percentage of initial dose duration. Bars represent SEM. ▲, pipecuronium; ●, vecuronium.

Discussion

The dose of vecuronium used in this study (0.2 mg.kg^{-1}), differs from that used in the previous study (0·15 mg.kg^{-1}) [4]. Isoflurane is known to potentiate the action of vecuronium [1], and the larger dose was used to allow a degree of clinical comparability between the duration of the initial dose of vecuronium in this study (mean 42.6 min) and that in the previous study (mean 48.6 min) [4].

The onset times observed in this study are in broad agreement with those reported previously [6,7]. The faster onset time in the vecuronium group is likely to be due to its inherently greater speed of onset and the fact that greater multiples of ED$_{90}$ of vecuronium were given than of pipecuronium. Our previous study [4] showed that the concomitant use of isoflurane gives rise to an increase in the duration of action of successive maintenance doses of pipecuronium, i.e. cumulation. This confirms previous observations of the potentiating effect of isoflurane on pipecuronium [2,3]. The absence of cumulation with pipecuronium in this study can be ascribed to our use of an anaesthetic technique that did not include a halogenated inhalational anaesthetic agent. Foldes *et al.* [8] reported that pipecuronium, even in the absence of halogenated inhalational agents, shows a tendency towards prolongation of effect. Our results do not support this finding. However, the anaesthetic technique used by Foldes *et al.* [8] (fentanyl, droperidol, nitrous oxide) differs from that used in this study (propofol, nitrous oxide). Neither the pipecuronium group nor the vecuronium group showed evidence of marked cumulation under the conditions pertaining in this study. We conclude that both pipecuronium and high-dose vecronium are suitable for use in long operations and that neither agent demonstrates significant cumulation with an anaesthetic technique that includes the use of nitrous oxide and a propofol infusion. The use of high-dose vecuronium in this setting may confer the advantage of a shorter onset time.

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Anaesthesia, 1992, Volume 47, pages 110–115

Late postoperative nocturnal dips in oxygen saturation in patients undergoing major abdominal vascular surgery

Predictive value of pre-operative overnight pulse oximetry

M. K. REEDER, M. D. GOLDMAN, L. LOH, A.D. MUIR, K. R. CASEY AND J. R. LEHANE

Summary

Twenty-four patients (23 male) who presented for aortic reconstructive surgery were studied with pulse oximetry on a pre-operative night and during the first five postoperative nights. Patients with five or more dips in oxygen saturation of greater than 4% (with a prompt recovery back toward baseline of 3% or more) per hour of monitoring were classified as having a significant abnormality of respiration. Pre-operatively, four of 24 patients (17%) demonstrated such an abnormality. Postoperatively, 12 patients (50%) met these criteria on at least one of the first five postoperative nights and six of these had two or more nights with severe episodic hypoxaemia. Frequent severe episodic dips in arterial oxygen saturation (to less than 85% saturation) occurred in the late postoperative period at a time when oxygen therapy would usually have been discontinued. Pre-operative overnight pulse oximetry studies fail to predict the development of abnormal respiratory patterns in the postoperative period in the majority of patients.

Key words

Surgery; abdominal.
Complications; postoperative hypoxaemia.
Measurement techniques; pulse oximetry.

Postoperative hypoxaemia may be persistent or episodic. Persistent hypoxaemia is usually the result of intrapulmonary complications which affect ventilation/perfusion relationships in the lung. Episodic hypoxaemia is usually the result of alterations in central neural respiratory drive to the respiratory and accessory respiratory muscles, which give rise to upper airway obstruction or periodic breathing patterns with central apnoea. These episodic phenomena occur almost exclusively during sleep.

Several studies [1–3] have shown that abnormal patterns of respiration occur commonly in the early postoperative period. Catley *et al.* [1] in 1985 observed frequent episodic dips in oxygen saturation in patients who received an intravenous infusion of morphine during the first 16 h after surgery. These episodes, which occurred only while patients were asleep, were associated with both central and obstructive apnoeas. A recent study in patients undergoing major abdominal surgery [2] has shown that episodic dips in arterial oxygen saturation occur during the second as well as the first night after surgery. These studies reflect respiratory patterns in the relatively early postoperative period. However, little is known regarding the incidence, duration and severity of episodic hypoxaemia during the late postoperative period when supplementary oxygen has normally been discontinued. Furthermore, the clinical significance of such episodes in the generation of morbidity in the postoperative period, particularly in patients at risk from ischaemic heart disease, is unexplored.

The aim of the present study was to document, in patients undergoing major abdominal vascular surgery, the pre-operative incidence of nocturnal episodic dips in arterial oxygen saturation, and to compare this with the incidence and severity of episodic nocturnal hypoxaemia occurring during the first five postoperative nights. We also wished to see whether a pre-operative overnight pulse oximetry study could predict patients who were likely to develop abnormal patterns of respiration in this late postoperative period.

Patients and methods

Twenty-four patients (mean age 68 years, range 30–82 years; 23 male) who presented for repair of aortic aneurysm or aorto-bifemoral graft procedures were asked to participate in the study. Routine management was not affected by inclusion in the study.

The study protocol consisted of the sampling of arterial oxygen saturation estimated by pulse oximetry ($Sp\text{O}_2$) and

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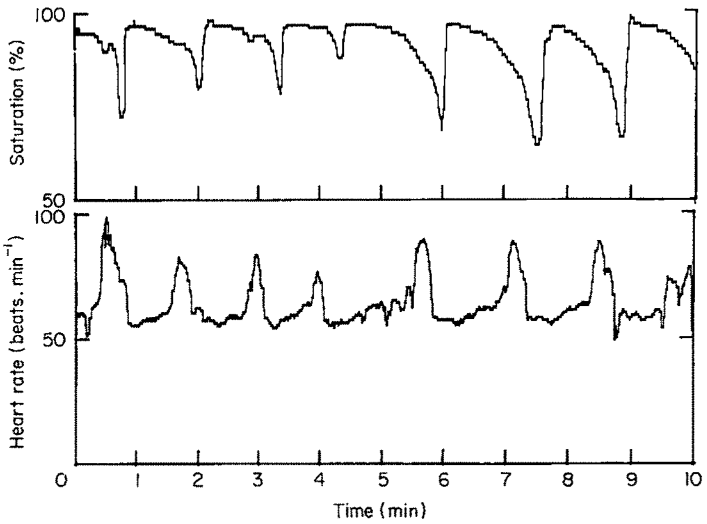

Fig. 1. Nocturnal oximetry. Typical 10-min tracings of Spo_2 (above) and heart rate (below) in a patient with significant respiratory abnormality caused by repeated airway obstruction. Note asymmetrical time course of de- and resaturation. Opening of the airway and hyperpnoea occurred simultanously with the cyclic increases in heart rate. Saturation trace is offset to the right because of the delay in detecting changes in saturation using a finger probe.

heart rate once each second by a portable microcomputer from an Ohmeda 3700 pulse oximeter on one night preoperatively and the first five postoperative nights. The oximeter probe was placed on a convenient finger and secured comfortably using adhesive tape.

A programme designed for respiratory sleep studies stored and displayed the data. 'Significant respiratory events' were identified visually and analysed manually to determine their incidence and nature. Significant respiratory events were defined as dips in Spo_2 of 4% or more with a prompt recovery of 3% or more. Patients were considered to exhibit a 'significant abnormality of respiration' (SAR) if they exhibited five or more such events per hour of study. In addition, the number of dips in Spo_2 below 85%, and the percentage of each night spent below 85% saturation, were recorded.

Figures 1 and 2 illustrate representative tracings of Spo_2 and heart rate fluctuations during respiratory events in two different patients. Figure 1 shows tracings in a patient observed to be breathing with obstructive apnoeas. Prolonged periods of obstruction (some in excess of 60 s) are associated with continuously falling Spo_2. The hyperpnoea which occurs at the ventilatory breakthroughs is associated with marked cyclic tachycardia, and is followed by rapid resaturation. These tracings are typical of those observed in patients with obstructive apnoea.

In contrast, Figure 2 shows Spo_2 and heart rate in a patient observed to be breathing periodically during a preoperative night. Desaturation and cyclic tachycardia are less severe, and a more symmetrical time course of de- and resaturation is evident. Additionally, cycle time is considerably shorter. In this patient, simultaneous monitoring of

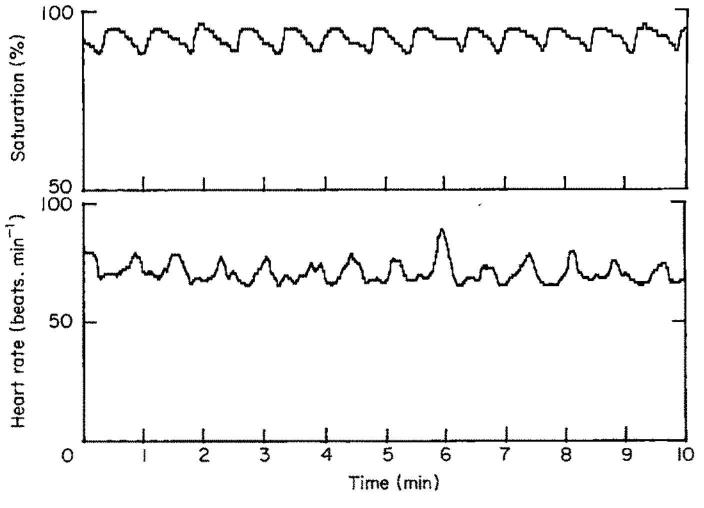

Fig. 2. Nocturnal oximetry. 10-min tracings of Spo_2 (above) and heart rate (below) in a patient observed to be breathing periodically during a pre-operative night. Note symmetrical time course of de- and resaturation along with more regular and shorter cycle times. Saturation trace is offset to the right because of the delay in detecting changes in saturation using a finger probe.

respiration with thoracic and abdominal strain gauges confirmed central apnoeas.

Since we wished to determine the normal incidence and severity of episodic dips in saturation in these patients, the usual pre-, intra- and postoperative management provided by the medical and nursing staff was unaffected by the study. No changes in oxygen therapy or pain relief were made. Patients were routinely prescribed supplementary oxygen (4–6 l.min^{-1}) via a Hudson face mask for the first two postoperative nights. However, oxygen delivery was often intermittent because several individuals removed their oxygen mask and spent prolonged periods of the first two nights breathing air. Supplementary oxygen was discontinued on the third postoperative day in all of the 24 patients.

All patients received intramuscular or intravenous opioid for control of pain during the first three postoperative days. The dosage of opioid received was not recorded as the study was an audit of late episodic dips in Spo_2 with current practice rather than a study relating abnormalities of respiration to any particular opioid regimen.

Results

Four of the 24 patients (17%) showed SAR during their pre-operative overnight study. Twelve of the 24 patients studied postoperatively (50%) suffered more than five dips per hour on at least one night, and 10 of these patients exhibited more than 10 dips per hour. The number of dips per hour in these 12 patients, including the four who desaturated pre-operatively, are shown in Table 1.

Table 1 also shows the worst postoperative night for each individual, in terms of frequency of dips. Six of the 12 patients who developed SAR postoperatively suffered their worst night in the late postoperative period during nights 4 or 5. Five of six patients who displayed SAR during night 3 postoperatively continued to retain the abnormal pattern through to night 5.

With regard to the severity of desaturation, Table 2 shows the total numbers of dips in Spo_2 to 85% saturation or below on each night. Several patients exhibited severe, frequent dips to very low saturations. Figure 3 shows a typical 10-min oximetry recording during the third postoperative night from patient 11 listed in Table 2. His respiratory instability and associated cyclic de- and resaturations, occurring on an already low baseline saturation, persisted throughout most of the night. Three patients (patients 9, 10, 12) spent an increased amount of time below 85% on night 5 compared with previous nights. These patients spent 40, 6, and 7% of the night respectively below 85% Spo_2. Over a 9-h study period (22.00–07.00), this represents a total of 216, 32, and 38 min respectively spent below 85% saturation on night 5.

Predictive value of pre-operative overnight pulse oximetry

The four patients identified as having SAR pre-operatively continued to have significant hypoxaemic events postoperatively up to the fifth postoperative night. However, we were unable to identify pre-operatively eight individuals who developed SAR postoperatively using the present definition of SAR as the criterion for sleep-related respiratory disturbance. We subsequently attempted to modify this criterion to determine whether we might have predicted pre-operatively more of those patients who developed postoperative disturbances of respiration. The original tracings of Spo_2 and heart rate were re-analysed, identifying individuals with five or more decreases of 3% in Spo_2 per hour associated with cyclic tachycardia, defined as a cyclic increase in heart rate of at least 10% of baseline [4, 5]. Using these broadened criteria, an additional four of the patients who developed SAR postoperatively could be identified from the pre-operative overnight monitoring. However, five of the 12 patients who did not develop SAR postoperatively also met these criteria.

Table 1. Average number of decreases in Spo_2 of 4% or more per hour during monitoring before and for five nights after operation in patients who developed significant abnormalities of respiration.

Patient	1	2	3	4	5	6	7	8	9	10	11	12
Pre-operative	0	1	2	0	1	0	1	1	14	35	42	5
Postoperative												
Night 1	2	1	0	0	5	0	0	0	0*	0*	1	3
Night 2	7	73	4	3	0	0	0	0	0	0	1	0
Night 3	20	0	9	32	0	0	0	60	0	4	89	9
Night 4	12	0	10	23	2	24	0	0	0	6	70	5
Night 5	7	0	5	19	0	0	8	0	10	16	64	41
Worst night	3	2	4	3	1	4	5	3	5	5	3	5

*Patients were observed to obstruct severely while on the intensive care unit. Supplementary oxygen prevented desaturation.

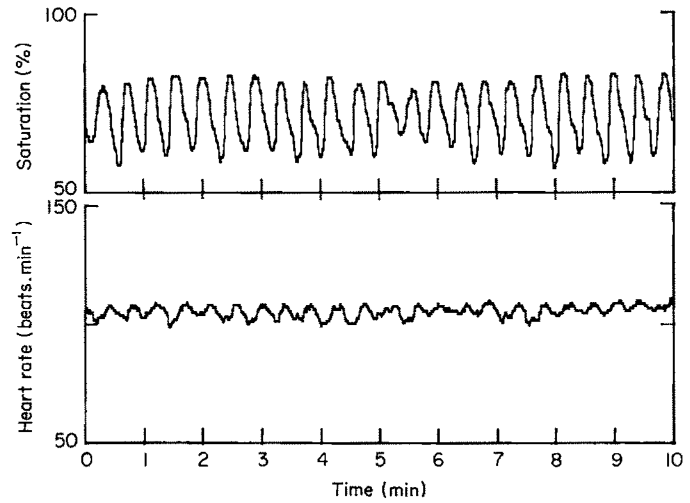

Fig. 3. Severe nocturnal episodic desaturations. Typical severe episodic desaturations on the third postoperative night in patient 11 (see Table 2).

Discussion

We confined our pulse oximetry monitoring to night hours because most patients would not tolerate five days of continuous monitoring in the postoperative period. The study was restricted to the period between 2200 and 0700 h on the following morning as the respiratory events which result in episodic dips in $S\text{po}_2$ were most likely to occur during sleep.

The state of central nervous system arousal (sleep vs wakefulness) was not monitored by electroencephalograph (EEG) in the present study. EEG monitoring, although noninvasive, is often disruptive to usual sleep patterns. Because the present study was undertaken to audit late postoperative hypoxaemia under conditions of usual current practice, we avoided disruptive monitoring techniques as far as possible. However, the episodic cyclic desaturation events observed in this study are most likely to have been due to altered patterns of ventilation. Furthermore, it may be argued that significant episodic obstruction of the upper airway and/or snoring and periodic breathing are unlikely to occur during wakefulness. Accordingly, we chose the criterion of five or more dips in $S\text{po}_2$ of greater than 4% per hour of nocturnal monitoring, to correspond with the physiological events commonly used to define sleep apnoea [6, 7].

The present definition of a significant respiratory event in terms of a change in saturation is open to debate. It may be argued that a 4% fall in $S\text{po}_2$ is not a large change. However, a reduction in $S\text{po}_2$ from 94% to 90% represents

Table 2. Pre- and postoperative total dips in $S\text{po}_2$ to less than 85% in patients developing significant abnormal respiration.

Patient	1	2	3	4	5	6
Pre-operative	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
Postoperative						
Night 1	0^{0}	0^{0}	0^{0}	0^{0}	35^{1}	0^{0}
Night 2	0^{20}	182^{2}	20^{13}	20^{11}	0^{0}	0^{0}
Night 3	177^{64}	0^{0}	25^{1}	92^{*13*}	0^{0}	0^{1}
Night 4	2^{0}	0^{0}	31^{8}	138^{12}	2^{0}	10^{1}
Night 5	0^{0}	0^{0}	16^{1}	32^{3}	0^{0}	0^{0}
Worst night	3	2	4	3	1	4
Patient	**7**	**8**	**9**	**10**	**11**	**12**
Pre-operative	0^{0}	0^{0}	68^{6}	63^{3}	0^{0}	0^{0}
Postoperative						
Night 1	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
Night 2	0^{0}	0^{0}	0^{0}	1^{0}	0^{0}	0^{0}
Night 3	0^{0}	0^{1}	0^{0}	13^{1}	229^{+43}	25^{4}
Night 4	0^{0}	0^{0}	0^{18}	44^{1}	84^{25}	2^{1}
Night 5	24^{0}	0^{0}	92^{40}	102^{6}	66^{8}	73^{7}
Worst night	5	—	5	5	3	5

Superscript = % of night spent at less than 85% $S\text{po}_2$.

$^{+}$Figure represents desaturations to less than 70% $S\text{po}_2$ and time spent at less than 70% $S\text{po}_2$. Baseline $S\text{po}_2$ below 85%.

* = Number of dips in $S\text{po}_2$ to less than 80% and % of time spent at less than 80% saturation. Patient's baseline $S\text{po}_2$ was at 86% during night 3.

a large decrease (approximately 3 kPa) in the partial pressure of oxygen and to produce this change a prolonged period of apnoea is likely to have occurred. A 4% decrease in Spo_2 from a lower baseline saturation, for example from 84% to 80% saturation, requires a much shorter period of apnoea, but may possibly be more harmful to the patient than more prolonged apnoeas at higher saturation.

Previous reports have emphasised that episodic hypoxaemia occurs early in the postoperative period [1–3]. In the present study, all patients were prescribed supplementary oxygen during the first two postoperative nights. It was not considered ethical to withhold current practice of routinely administering supplementary oxygen for up to 48 h following aortic reconstructive surgery. Therefore, it is likely that monitoring by pulse oximetry failed to detect some of the respiratory events that occurred during this period. As a result, the prevalence of significant abnormalities of respiration in the early postoperative period has undoubtedly been underestimated. Indeed, some patients who removed their oxygen mask during the first two days were noted to have episodic dips in Spo_2. Patients 9 and 10 (Table 1) were observed to manifest airway obstruction repeatedly during their first postoperative night while on supplementary oxygen in the Intensive Care Unit.

It would appear that despite prescription of oxygen for the first two postoperative days, many cardiovascular surgical patients experience frequent severe episodic desaturations in the later postoperative period, up to the fifth night. They are therefore at risk of spending a significant amount of time at low saturations in the late postoperative period when overnight oxygen therapy would normally no longer be considered necessary.

None of the patients with significant respiratory abnormalities pre-operatively was suspected of having abnormal nocturnal respiratory patterns before admission. Since all patients with pre-operative SAR experienced SAR postoperatively, a positive result from pre-operative nocturnal monitoring can be used to predict the likely development of significant respiratory abnormalities during the postoperative period. Treatment such as nasal CPAP or more prolonged use of overnight oxygen therapy can accordingly be planned in advance. However, the pre-operative nocturnal oximetry study identified only a small proportion of the group at risk of postoperative SAR in the present study.

Factors contributing to respiratory instability

Opioids and other sedatives are likely to play an important role in the development of postoperative respiratory patterns. Catley *et al.* [1] noted that central and obstructive apnoeas occurred more frequently in patients who had received intravenous morphine postoperatively than in patients treated with regional anaesthesia. Hypoxaemia itself increases peripheral chemoreceptor activity which may promote the initiation of periodic respiration [8, 9].

The pattern of sleep in the postoperative period is of importance in the production and severity of abnormal respiratory patterns. Knill *et al.* [10, 11] noted that sleep after surgery for gastroplasty was markedly disturbed, with complete absence of rapid eye movement (REM) and slow-wave sleep on the night of surgery. Stages I and II sleep, which are associated with respiratory instability, occur during the first postoperative night. Slow-wave and REM sleep return on the second to fourth postoperative nights, with subsequent REM rebound [11]. Knill *et al.* noted an increase in the numbers of apnoeas and episodic desaturations on these nights, especially during REM sleep [10].

Although obstructive apnoeas occur during all stages of sleep, they are more frequent and of greater severity during periods of REM sleep [6, 11]. In REM sleep, neural drive to the pharyngeal muscles is at a minimum and the airway is less well protected against obstruction by the tongue and surrounding soft tissues. Return of REM sleep in the late postoperative period may worsen episodic upper airway obstruction in a susceptible individual. The appearance or the worsening of episodic dips in Spo_2 in vascular patients in the present study in the late postoperative period may reflect, in part, the return of REM sleep.

In conclusion, we have shown in a group of elderly patients who underwent abdominal vascular surgery that significant respiratory abnormalities occur in the late postoperative period when, normally, supplementary oxygen has been discontinued in most centres. Such patients have an increased prevalence of associated cardiac impairment; a recent study [12] and our own unpublished observations have demonstrated temporal associations between reductions in Spo_2 and the development of significant ST segment depression in the postoperative period. Because obstructive and central apnoeas are asociated with decreases in Spo_2 and cyclic tachycardia and hypertension, they may be expected to be harmful to patients with ischaemic heart disease. However, further work is needed to determine the role of episodic dips in oxygen saturation in the development of cardiac dysfuntion in the postoperative period [13].

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Cause of death after critical illness

S. RIDLEY AND J. PURDIE

Summary

This study reports the causes of death after discharge following treatment of life-threatening illness on an Intensive Therapy Unit. Details of survivors discharged between June 1985 and December 1988 were sent to the Registrar General for Scotland who subsequently issued copies of death certificates of those patients who had died between discharge and 1 January 1990. The results show that the commonest causes of death after discharge were malignancy and respiratory failure, although there is wide variation in the post-discharge mortality rates for different diagnostic categories. The admission diagnoses were identical to, or contributed to, the causes of death in 64% of patients who died after discharge. Eighty-five percent of patients who died from the same condition which prompted admission did so within a year following discharge, but after 2 years no deaths were attributed to the admission diagnosis.

Key words

Intensive care; causes of death.

Patients admitted to an Intensive Therapy Unit (ITU) may be categorised into different groups according to age, severity of illness, diagnosis and ITU mortality [1–3]. However in the United Kingdom, little information is available concerning the survival of patients after discharge [4–6] and no study has reported causes of death after discharge following critical illness. Therefore the aims of this study were: to report the primary causes of death in patients discharged from a typical ITU; to investigate whether the cause of death was related to the ITU admission diagnosis; and to establish whether the relationship varied with the duration of survival.

Methods

All patients discharged from ITU at the Western Infirmary, Glasgow, between June 1985 and December 1988 were studied. The patients' age, diagnosis and severity of illness, as quantified by the Acute Physiology and Chronic Health Evaluation (APACHE II) score [7] were recorded on admission.

Details of all survivors were sent to the Registrar General for Scotland, who issued copies of death certificates for patients who had died between discharge and 1 January 1990. Patients were therefore followed for between 1 and 4.5 years, depending upon the date of admission.

Patients who had died since discharge were then classified in the following manner: group 1, patients whose primary cause of death matched the ITU admission diagnosis; group 2, patients whose ITU admission diagnosis was not the primary cause of death but was listed as a secondary cause of death or a contributing factor on the death certificate; group 3, patients whose cause of death was unrelated to the ITU admission diagnosis.

The Chi-squared, Wilcoxon ranked sum, Kruskal–Wallis tests and one-way analysis of variance were used for statistical analysis. A p value of < 0.05 was considered significant and 95% confidence limits are shown in parentheses where appropriate.

Results

During the study period, 763 patients were discharged from ITU. Up to 1 January 1990, 180 patients were known to have died, although the Registrar General could provide copies of the death certificates for only 158 patients; in 24%, the cause of death was confirmed at postmortem. The missing 22 patients had either been resident elsewhere in the UK at the time of their critical illness or had moved from Scotland since discharge. However, there were no

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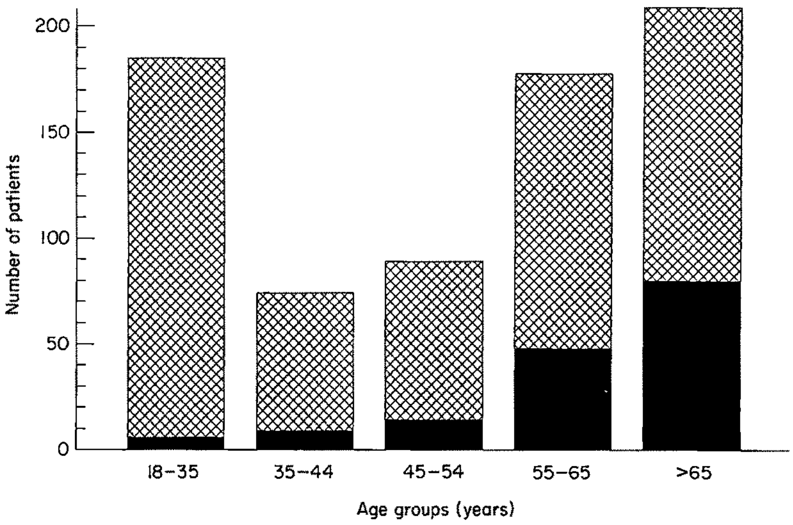

Fig. 1. Age distribution of all patients discharged from ITU. Cross-hatched areas represent survivors and solid areas represent patients who died after discharge (five patients are omitted because age was not recorded).

significant differences between these patients and those for whom death certificates were available in respect of age, severity of illness, survival and diagnosis.

The distributions of age, severity of illness and diagnoses of all 763 patients discharged from ITU are shown in Figures 1 to 3. Fifty-two (48–56) percent of the patients discharged were over 55 years old and the proportion of patients who died after discharge increased with age (Fig. 1). The median APACHE II score was 13 (12–14) and the proportion of patients who died after discharge increased with increasing APACHE II score (Chi-square = 33, df = 5, $p < 0.01$; Fig. 2). The commonest reason for admission was for respiratory support, either postoperatively or as a result of respiratory failure (256 (34%) patients; Fig. 3). There was significant variability in mortality rates after discharge among the diagnostic categories ($p < 0.05$). Patients admitted to ITU with gastrointestinal pathology and respiratory failure had high post-discharge mortality (39 (29–49)% and 34 (23–45)% respectively). Trauma and poisoning (which has been included in the 'miscellaneous' group) had much lower post-discharge mortality (3.5 (0–7.5)% and 6 (0–13)% respectively).

The distribution of primary cause of death in relation to ITU admission diagnosis in the 158 patients for whom death certificates were available is illustrated in Table 1. The two commonest causes of death after discharge from the ITU were malignancy (49 patients (31 (24–38)%)) and respiratory failure (30 patients (19 (13–25)%)).

There were 33 patients (21 (15–27)%) in group 1 and of these, 85 (73–97)% had died within one year. Group 2 was the largest group (68 patients (43 (35–51)%)); however, 31 of these patients were admitted for high dependency care following major surgery for the cancer that finally caused their demise. Twenty-five of these patients had an APACHE II score of 15 or less. In 57 patients (36 (28–44)%, group 3) the cause of death was unrelated to the admission diagnosis.

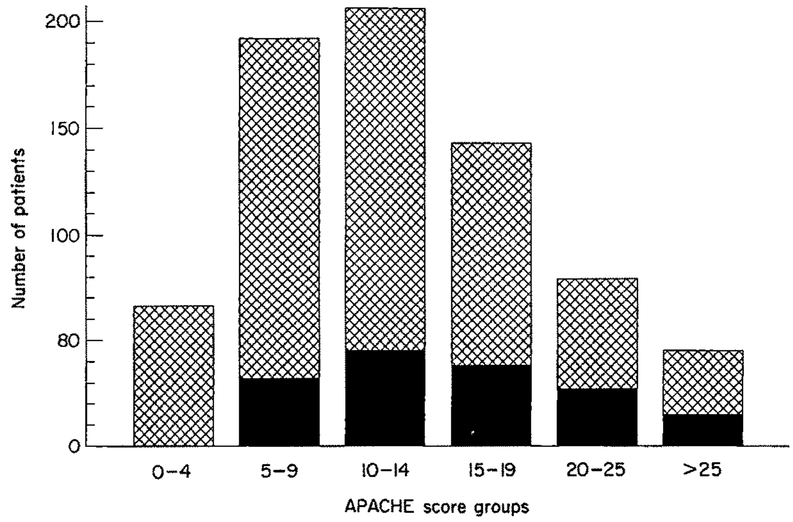

Fig. 2. Distribution of severity of illness on admission of all patients discharged from ITU. Cross-hatched areas represent survivors and solid areas represent patients who died after discharge. APACHE II scores were not calculated in nine patients because of incomplete physiological data.

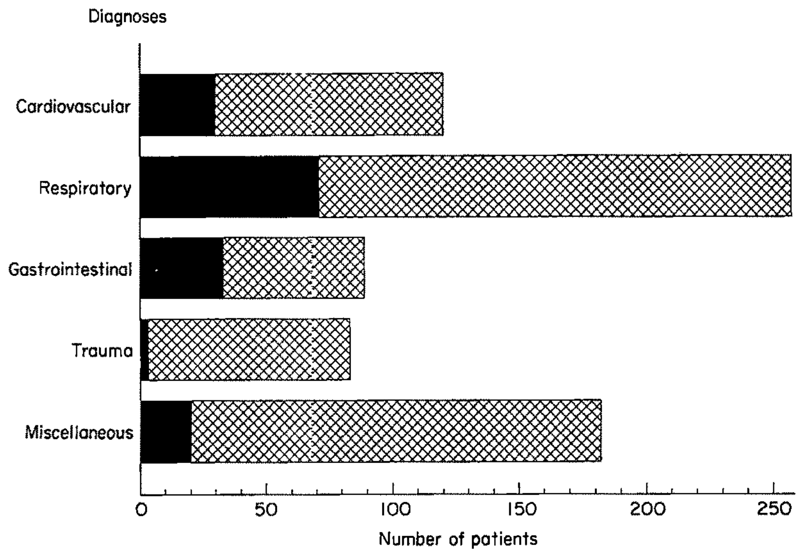

Fig. 3. Distribution of diagnoses necessitating ITU admission in those patients who were discharged. Cross-hatched areas represent survivors and solid areas represent patients who died after discharge. Nine patients are omitted because the diagnosis was not recorded.

Figure 4 shows that the relationship between admission diagnosis and cause of death varied with time after discharge. Fifty-six (48–64) percent of deaths occurred within 6 months and 73 (66–80)% within 1 year. However, there were no significant differences in survival among the three groups. The APACHE II scores of patients in group 1 were significantly higher than in the other two groups (median APACHE II score: group 1 = 19 (16–20); group 2 = 12 (11–14); group 3 = 15 (13–16)). There were no differences among the groups in respect of age or duration of admission.

Discussion

The distribution of causes of death after ITU management is clearly dependent upon the types of patient admitted and the reliability of information given on the death certificates. The ITU at the Western Infirmary is a regional unit which accepts approximately 20% of its patients from other hospitals. All types of patient are admitted except those with neurosurgical problems, who are treated at another hospital in Glasgow. However, the ITU at the Western Infirmary admits a wide range of critically ill patients and so may reflect the workload of a typical British ITU.

Clinical identification of the causes of death may be inaccurate unless confirmed by postmortem examination. Cameron [8] reported that 15% of main diagnoses and 42% of causes of death in hospitals were not confirmed by necropsy. A more recent American study has confirmed the discrepancy between pre- and postmortem causes of hospital death as 34% [9]. However, it is not known whether the cause of death may be more reliable when death occurs in the community and at present, unless the necropsy rate increases dramatically, the best available information concerning cause of death comes from the death certificate.

The high percentage of elderly patients, who were usually admitted to ITU at the Western Infirmary for high dependency care immediately after major surgery, may account for malignancy being the commonest cause of death after

Table 1. The distribution of ITU admission diagnoses and cause of death in 158 patients for whom death certificates were available.

	Causes of death								
Diagnosis	Trauma	Respiratory failure	Cancer	Poisoning	Arrest	Neuro	CVS	GIT	MISCEL
Trauma	3		1						1
Respiratory failure		12	5	1		2	5	2	3
Postoperative (not cancer)		4	6	1	1	2	6		2
Postoperative (cancer surgery)		2	20			1	1		
Poisoning			1	2			1		1
Cardiac arrest (arrest)					1				
Neurological (neuro)						2	2		
Cardiovascular (CVS)		5	7			5	9	1	4
Gastrointestinal (GIT		7	9		1	2	8	3	3
Miscellaneous (MISCEL)					1	1			1

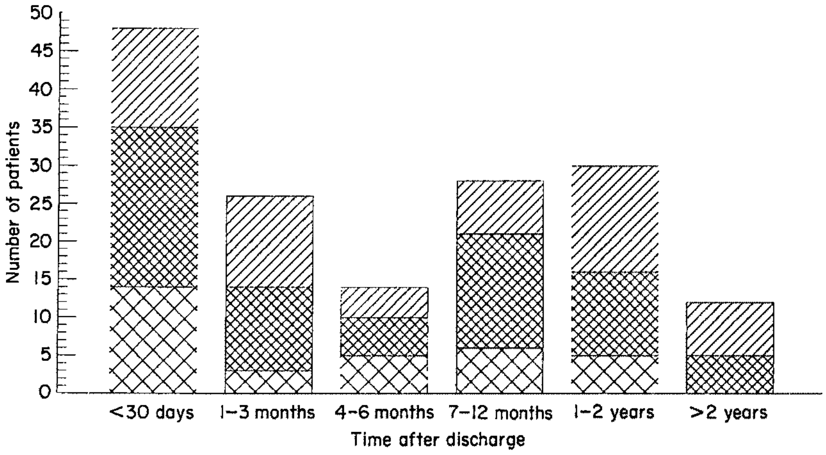

Fig. 4. A histogram showing the matching of admission diagnosis and cause of death at various times after discharge in 158 patients for whom death certificates were available. Wide cross-hatched areas represent good match (group 1); narrow cross-hatched areas represent some relationship between diagnosis and death (group 2); diagonal lines represent no match (group 3) (See text).

discharge. A recent Danish study [10] reported that cancer was the predominant cause of death after discharge from ITU and that death from respiratory causes became more frequent with longer survival. The findings of the present study are similar. The results also suggest that some diagnoses, such as gastrointestinal pathology and respiratory failure, are associated with a poor prognosis. A possible explanation is that in the case of respiratory failure, ITU management is required for treatment of an acute exacerbation of a chronic disease, and that gastrointestinal pathology frequently involves malignancy or severe sepsis. Acute self-limiting conditions such as trauma or poisoning appear to have a better prognosis.

The admission diagnoses were identical to, or contributed to, the causes of death in 64% of patients who died after discharge (groups 1 and 2). However the matching of admission diagnosis and eventual cause of death was not related to duration of survival. The lasting effects of critical illness are unknown, but may have contributed to the high percentage of matching found in this study. Furthermore the higher APACHE II scores in group 1 may indicate that severity of illness on admission also influences the cause of death.

Acknowledgment

The authors wish to thank Mrs Bain, Studies Section, Office of the Registrar General for Scotland, for her help in providing copies of the death certificates.

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Anaesthesia, 1992, Volume 47, pages 120–124

Suprascapular nerve block

A new approach for the management of frozen shoulder

M. R. WASSEF

Summary

A new approach for the management of frozen shoulder associated with reflex sympathetic dystrophy is presented. A suprascapular nerve block was performed by needle insertion behind the lateral end of the clavicle at its junction with the insertion of the trapezius muscle; the needle was directed downwards and backwards. The suprascapular nerve was identified by its response to nerve stimulation. Three ml of 0.25% bupivacaine with 1:200 000 adrenaline was injected. The block was repeated twice weekly for a total of 2–4 treatments. Evaluation of the efficacy of the block was achieved by comparing subjective pain scores and passive range of movement before the first block and after the final one. Highly significant improvements were obtained. The choice of blockade of the suprascapular nerve is a new concept for the management of the frozen shoulder of reflex sympathetic dystrophy. This is based on the fact that the nerve contains a high proportion of sympathetic fibres supplying the shoulder joint. The new approach proved to be simple, highly successful, and reproducible.

Key words

Anatomy; nerve, suprascapular.
Anaesthetic technique; regional, suprascapular nerve.
Complications; reflex sympathetic dystrophy.

The term 'frozen shoulder' is used to describe a painful stiffness of the shoulder joint characterised by limitation of movement. Various aetiological factors could give rise to this condition including the shoulder–hand syndrome of reflex sympathetic dystrophy (RSD) [1]. Clinically, the frozen shoulder may be the only presenting sign of RSD or it may be associated with hand involvement. A sizeable proportion of frozen shoulder cases have been found following myocardial infarction, hemiplegia and other disorders [2]. The management of the frozen shoulder associated with RSD includes physiotherapy and sympathetic blockade in the form of stellate ganglion or brachial plexus block [3].

Shoulder pain, in general, can be alleviated by suprascapular nerve block [4]. The technique of suprascapular nerve blockade, as described in textbooks, involves a posterior approach, the needle entering above the scapula [5]. Since sympathetic fibres supplying the shoulder joint run in the suprascapular nerve, it is conceivable that sympathetic blockade to the shoulder could be achieved at the level of this nerve.

The aim of this study was to present a new and simple approach to the suprascapular nerve, whereby the needle is inserted via an anterior approach above the clavicle. and to evaluate its efficacy in the management of the frozen shoulder of reflex sympathetic dystrophy.

Methods

Institutional approval was given for the study and informed consenting patients with the diagnosis of frozen shoulder associated with reflex sympathetic dystrophy were referred for pain relief management. All patients complained of diffuse dull pain, tenderness and variable swelling of the affected shoulder joint, and limitation in range of passive movement. The case history of the frozen shoulder was reviewed for each patient. Demographic data obtained included age, sex, duration of shoulder pain and disability and presumed aetiology. Symptoms were graded according to severity of the pain; grade 1: severe, grade 2: moderate and grade 3: mild. The patient evaluation consisted of the following: (a) objective joint pain score: this was obtained by palpation of the glenohumeral joint and scored as follows: 0 = no pain, 1 = mild pain to deep palpation, 2 = severe pain to deep palpation, 3 = severe pain to mild palpation and 4 = hyperaesthesia. (b) passive range of movement score (PROM): this was determined as follows: (1) ability to elevate the arm through 180°,

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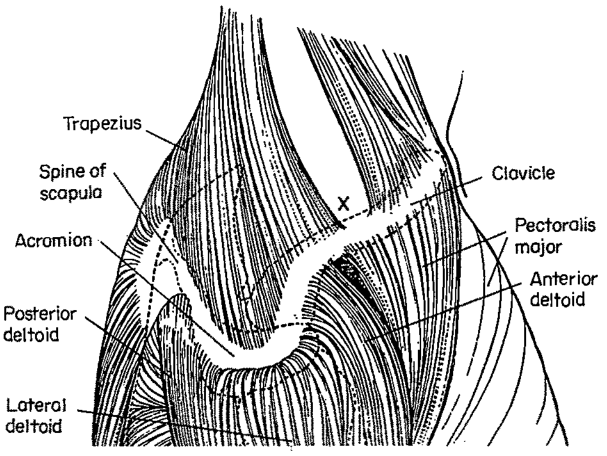

Fig. 1. A lateral view of the shoulder depicting the point of needle entry, marked X, at the junction of the trapezius muscle and the clavicle.

(2) ability to elevate the arm above the horizontal level, (3) ability to elevate the arm to the horizontal level, (4) ability to elevate the arm to below the horizontal level and (5) inability to move the arm. Active range of movement was not measured in this study since most of the patients had CNS-related conditions. (c) Visual analogue score (VAS): the patient was asked to mark a 100 mm scale where 0 indicated no pain and 100 indicated extreme severe pain.

These tests were carried out prior to the first block and after the final one.

Anatomy

The suprascapular nerve is a large nerve which arises from the upper trunk of the brachial plexus. It runs laterally, posteriorly and inferiorly deep to the omohyoid and trapezius muscles, but superficial to the brachial plexus, to reach the superior border of the scapula. Here it passes through the suprascapular notch and enters the supraspinous fossa, where it gives off several branches including articular branches to the acromioclavicular and the shoulder joints. It then runs deep to the supraspinatus muscle and curves round the lateral border of the spine of the scapula to gain the infraspinous fossa where it gives off more branches including articular filaments to the shoulder joint.

The coracoid process arises from the upper border of the head of the scapula and is bent sharply so as to project forwards and slightly laterally. Its medial margin is almost aligned with the suprascapular notch, and its tip can be felt through the skin [6].

Technique

The patient is placed in the sitting position. The landmarks used are the coracoid process, the trapezius muscle and the clavicle. The point of entry of the needle is marked at the junction of the medial border of the trapezius muscle and the posterior border of the lateral third of the clavicle (Fig. 1). This point is above the clavicle, and lies at the apex of a triangle set in the perpendicular plane whose base is a line formed by the medial side of the tip of the coracoid process anteriorly and the suprascapular notch posteriorly (Fig. 2). Under aseptic conditions a 22 gauge needle was inserted and directed backwards and downwards with slight medial inclination, along the posterior side of the triangle. A peripheral nerve stimulator was employed for identification of the suprascapular nerve. Nerve blockade was produced by injection of 3.0 ml of 0.25% bupivacaine with 1:200 000 adrenaline. All blocks proved to be uneventful.

The block was repeated twice weekly. The total number of blocks for each patient varied according to the diminution of pain and improvement in the passive range of shoulder movement. During and after suprascapular nerve block therapy, patients were maintained on a physiotherapy programme.

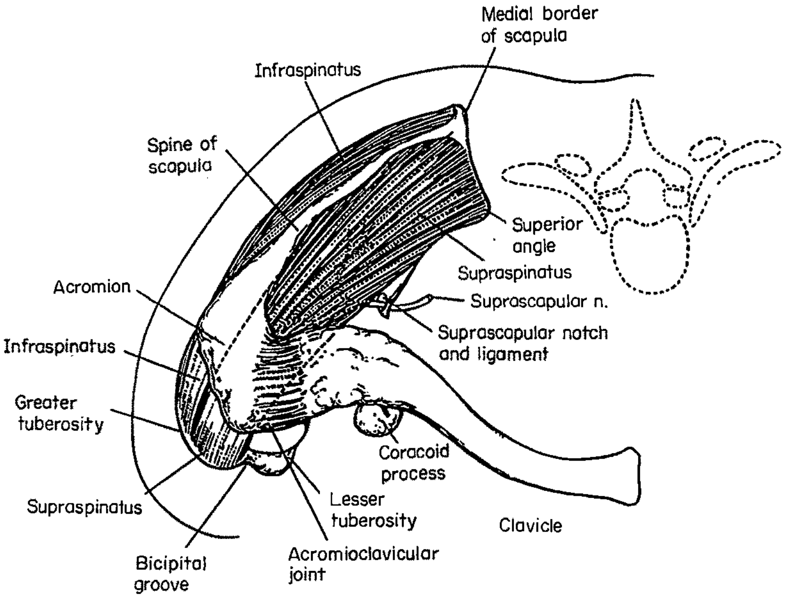

Fig. 2. Superior view of the shoulder depicting the suprascapular nerve in relation to the clavicle and the coracoid process.

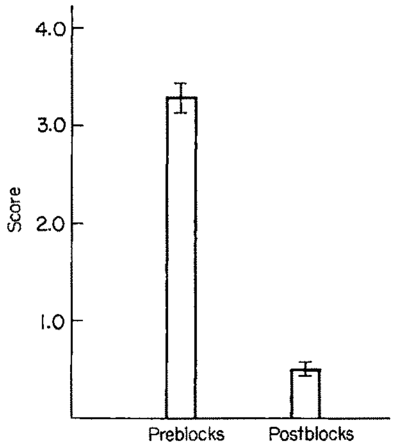

Fig. 3. Objective joint pain score before and after the suprascapular nerve block therapy.

Analysis of data

Data of various parameters were calculated as mean (SD). Comparison between the parametric variables were performed using Student's *t*-test. Statistical significance was considered at a level of $p < 0.05$.

Results

Patient characteristics

Nine patients with the frozen shoulder of RSD received suprascapular nerve block therapy. Their mean age was 60.33 (SD 5.41) years (range 32–76) and all were female. The precipitating aetiological factors were mainly central nervous system pathology resulting in paraplegia in five patients, cervical cord injury in one, brachial plexus injury in one patient and trauma in two patients. The mean time between the development of symptoms and evaluation was 9.56 (SD 1.09) months (range 2–12). The mean number of blocks performed was 3.22 (SD 0.4) (range 2–4). Depth of needle insertion was 3.90 (SD 0.19) cm (range 3–5 cm).

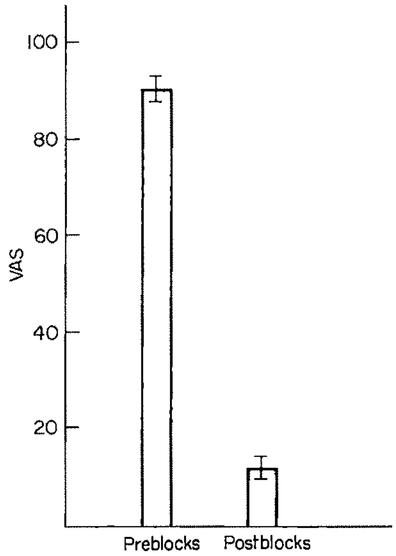

Fig. 4. Visual analogue scale (VAS) before and after the suprascapular nerve block therapy.

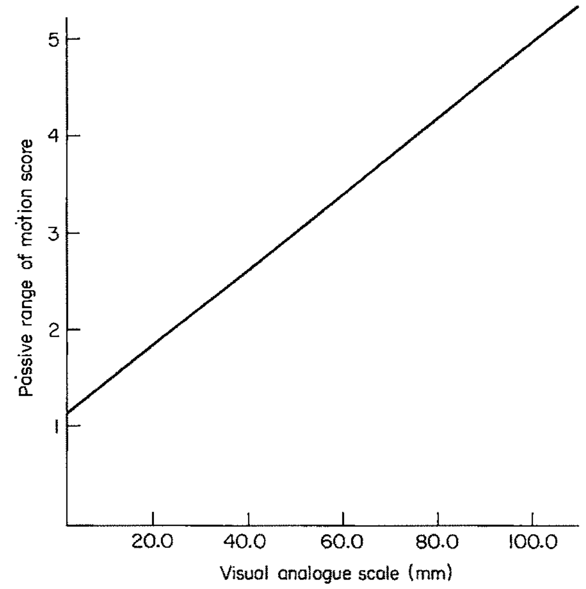

Fig. 5. Correlation between the visual analogue scale and the passive range of movement, before and after the suprascapular nerve block therapy. $Y = 1.052 + 0.039X$; $r = 0.986$; $p < 0.001$.

Frozen shoulder characteristics

All patients presented with the shoulder component of RSD affecting one side only. The chief complaint was shoulder pain and restricted active movement in the nonparaplegic patients. Symptom grades were: grade 1 (severe) in three patients and grade 2 (moderate) in six patients. The presenting sensory phenomena associated with pain were hyperaesthesia in all patients (100%) and hyperalgesia in six. The subjective description of pain in grade 1 patients ($n = 3$) was burning in one and lancing in two while in all grade 2 patients ($n = 6$) it was dull and aching.

Pain scores

There was a significant decrease in the mean objective joint pain score indicating improvement in the patient's tolerance to deep pressure applied to the shoulder joint. Overall scores before and after the block therapy were 3.11 (SD 0.11) and 0.56 (SD 0.18) respectively, $p < 0.001$, (Fig. 3).

There was a significant decrease in the visual analogue scores (VAS) indicating the patient's appreciation of pain alleviation. Mean scores before and after the block therapy were 85.56 (SD 2.94) and 12.78 (SD 3.55) respectively, $p < 0.001$. The mean percentage of improvement was 86.00 (SD 3.72) (Fig. 4).

A highly significant correlation was found between the visual analogue score and the passive range of movement obtained before and after the blocks $r = 0.986$, $p < 0.001$. The regression equation calculated was; $Y = 1.052 + 0.039$ X, where Y is the passive range of movement score, and X is the visual analogue score in mm (Fig. 5).

A significant improvement was obtained in the passive range of movement (PROM) score. The mean scores before

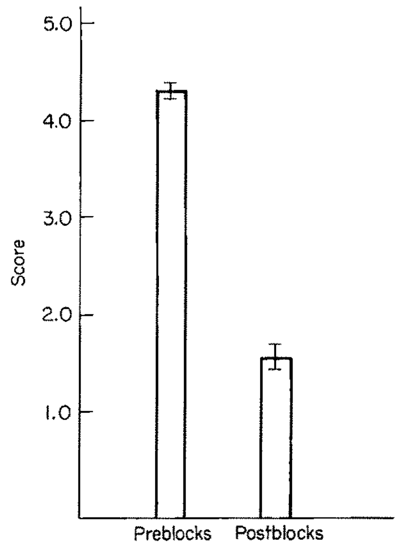

Fig. 6. Passive range of movement (PROM) score of the shoulder before and after the suprascapular nerve block therapy.

and after the block therapy were 4.33 (SD 0.50) and 1.56 (SD 0.18) respectively $p < 0.001$, (Fig. 6).

Discussion

The frozen shoulder is frequently described as either the sole presenting manifestation or a component of the shoulder–hand syndrome of reflex sympathetic dystrophy (RSD) [1]. Two common aetiological factors are associated with this disease, namely myocardial infarction and hemiplegia, although other factors such as trauma could predispose. The relationship between hemiplegia and the signs and symptoms of the shoulder–hand syndrome was emphasised by deTakats [7] and Evans [8]. In posthemiplegic shoulder–hand syndrome patients the pain and restricted movement disappears with sympathetic blockade [9], in conjunction with a programme of physiotherapy.

Suprascapular nerve block is said to be useful in the management of severe painful conditions of the shoulder joint, but there is little reference to the use of suprascapular nerve block for the management of pain in the frozen shoulder of RSD. The present work showed that the anterior approach to blockade of the suprascapular nerve produced a highly significant reduction of pain and improved passive range of movement in the frozen shoulder of RSD.

There were two aims behind this work: to present a new approach to blockade of the suprascapular nerve, and to demonstrate the efficacy of this block in the management of the frozen shoulder of RSD.

The anterior approach is of particular value with bedridden patients as it can be performed while the patient is lying in bed. All that is required is exposure of the front part of the shoulder and neck. The traditional posterior approach requires turning and positioning; a strenuous task for the nursing staff as well as for the patient. The anterior approach proved to provide an easy and reproducible access to the suprascapular nerve.

Suprascapular nerve block produces sympathetic blockade similar to that obtained with stellate ganglion

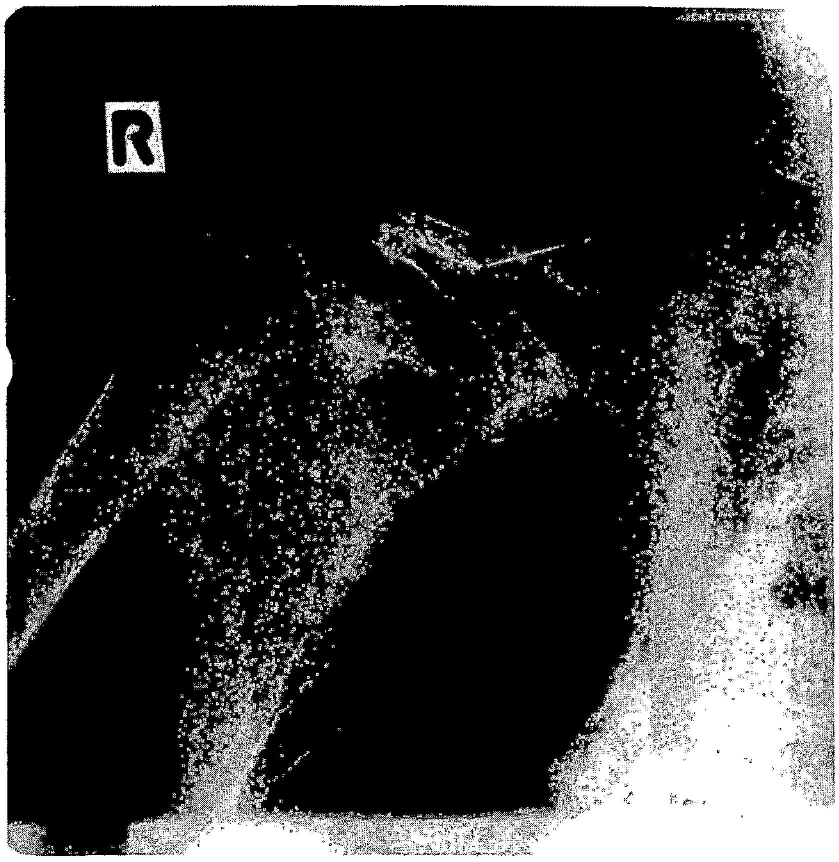

Fig. 7. X ray of the shoulder area after injection of local anaesthetic mixed with radio-opaque material.

blockade but spares the patient from the inherent risks of the latter technique [10]. The most serious complication of the traditional approach to suprascapular nerve blockade is pneumothorax; the incidence is reported to be less than one percent [11]. This can occur if the needle is passed above the upper border of the scapula and advanced too far anteriorly, piercing the lungs. It is highly unlikely for this complication to occur with the anterior approach, since the needle is directed posteriorly and from a higher angle. Also, the point of needle entry is away from the dome of the lung and its direction is in a plane which is perpendicular to the ribs. This makes penetration of the intercostal space highly unlikely. Figure 7 is an X ray showing the needle away from the thoracic cage. The needle tip is superficial to the suprascapular notch, showing that the suprascapular nerve can be blocked at a superficial level and before it reaches the suprascapular foramen.

A number of hypotheses have been proposed concerning the mechanism of reflex sympathetic dystrophy [12, 13]. Roberts [14] suggested that trauma initially activates unmyelinated C-nociceptors, which in turn activate and sensitise wide dynamic range (WDR) neurones in the dorsal horn whose axons ascend to higher centres. This sensitisation persists, so that the WDR neurones now respond to activity in large-diameter A-mechanoreceptive low threshold afferents, which are activated by light touch or brushing. Moreover, these sensitised WDR neurones respond to A-mechanoreceptive activity initiated by sympathetic efferent action on sensory receptors in the absence of cutaneous stimulation and thus produce spontaneous pain or what Roberts calls 'sympathetically mediated pain'. Nathan [15] has used the abnormal state of the dorsal horn as an explanation for RSD caused not only by limb injury but also by central nervous system pathology.

In conclusion, sympathetic blockade at the level of the suprascapular nerve for the management of the frozen shoulder of RSD proved to be a highly specific procedure, in terms of sympathetically mediated shoulder pain. The anterior approach to the suprascapular nerve is a new, simple, convenient and reproducible technique offering easy accessibility to the suprascapular nerve in the bedridden patient, as opposed to the traditional posterior approach.

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Anaesthesia, 1992, Volume 47, pages 125–127

CASE REPORT

Torsade de pointes and long QT syndrome following major blood transfusion

P. KULKARNI, S. BHATTACHARYA AND A. J. PETROS

Summary

We report a rare complication following transfusion of a large volume of blood in an adult patient. An electrophysiological disturbance of the cardiac cycle with prolongation of the QT interval developed, which was followed by recurrent episodes of torsade de pointes, a unique form of ventricular tachycardia. The most likely cause of this acquired long QT syndrome was hypomagnesaemia secondary to massive blood transfusion. Treatment with a magnesium infusion restored the QT interval to normal and temporary ventricular pacing prevented further ventricular arrhythmias.

Key words

Heart; arrhythmia, ventricular, torsade de pointes.
Ions; magnesium.
Transfusion; complications.

Case history

A 39-year-old woman, gravida 2, para 2, presented with severe postpartum haemorrhage 4 weeks after Caesarean section and the delivery of a female infant of 31 weeks' gestation. She had a systolic blood pressure of 90 mmHg and was clinically shocked.

Initial investigations revealed a haemoglobin concentration of 5.5 $g.dl^{-1}$, with normal coagulation studies (Table 1). After resuscitation with 3.2 l of blood, 2 l of plasma protein fraction and 500 ml fresh frozen plasma, she was taken to the operating theatre for examination under anaesthesia. No cause for the bleeding was found, and a dilatation and curettage was performed. The patient was then transferred to the intensive care unit (ICU).

While on the ICU she developed signs of septic shock; she became pyrexial (38.6°C) and hypotensive, with a systolic blood pressure of 80–90 mmHg. She had a cardiac output of 8.8 $l.min^{-1}$ and a systemic vascular resistance (SVR) of 400 dynes $s.cm^{-5}$. Antibiotics (cefuroxime and gentamicin) and inotropes (noradrenaline and dopamine, 2–3 $\mu g.kg^{-1}.min^{-1}$) were started. Her SVR rose to 1500 dynes $s.cm^{-5}$ as a result of this treatment and she maintained a systolic blood pressure of 90–100 mmHg and a good urine output.

Ten hours after surgery she developed episodes of polymorphous ventricular tachycardia, which initially lasted for 1–2 min and stopped spontaneously, but subsequent episodes progressed to ventricular fibrillation and syncope, and required direct current (DC) cardioversion. She was treated with lignocaine, but this did not prevent the occurrence of further episodes of ventricular tachycardia.

A twelve-lead electrocardiogram (ECG) showed normal sinus rhythm, with normal PR and QRS intervals (Fig. 1), but the QT interval corrected for heart rate (QTc) was abnormally prolonged at 0.61 s (normal < 0.44 s). Plasma potassium and calcium (corrected) were within the normal range, but the plasma magnesium level was abnormally low (0.48 $mmol.l^{-1}$). The normal range in our laboratory is 0.6–1 $mmol.l^{-1}$ (Fig. 2).

In the absence of a previous or family history of syncope, a diagnosis of acquired long QT syndrome with ventricular tachycardia (torsade de pointes) secondary to hypomagnesaemia was made. Magnesium was administered intravenously at a rate of 60 mmol over 6 h. This only transiently increased the plasma level, and further magnesium administration was required to maintain levels in the normal range. In spite of the magnesium infusion there were recurrent episodes of ventricular tachycardia for which the patient required DC cardioversion. In view of this, temporary ventricular overdrive pacing was started, and this prevented further episodes of the arrhythmia. Pacing was discontinued after 5 days and the arrhythmia

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Table 1. Laboratory investigations from admission to the postoperative period on the ICU.

Time	Haemoglobin; g.dl^{-1}	Corrected calcium; (normal range 2.16–2.58 mmol.l^{-1})	Magnesium; (normal range 0.6–1.0 mmol.l^{-1})	Potassium (normal range 3.8–5.2 mmol.l^{-1})	Q_T/Q_{TC} (400/529 ms)
Pre-operative	5.5	—	—	3.9	—
Postoperative 10 h	11.0	2.61	—	3.3	272/398
24 h	14.3	2.17	0.48	—	500/608
36 h	14.6	—	1.45	5.2	—
48 h	15.5	2.47	0.62	4.2	—

QTc; QT interval corrected for heart rate.

did not recur. The QTc returned progressively to normal (Fig. 2).

Discussion

Torsade de pointes is a term which describes the ventricular tachyarrhythmias which can occur in the setting of QT interval prolongation and the development of abnormal T and U waves, and refers to the 'twisting' morphology of the QRS complexes that is often, but not always seen [1–4]. The QT interval is dependent on heart rate, and is corrected using the formula QTc = QT/RR [5]. Values of QTc greater than 0.44 s are abnormal.

The long QT interval syndromes (LQTS) are classified as acquired or pause dependent, and congenital or adrenergic dependent [3, 4]. In the acquired LQTS, arrhythmias usually follow pauses i.e. a long diastolic isoelectric interval precedes the sinus beat that initiates the arrhythmia. Causes of acquired long QT syndrome include drugs (class IA antiarrhythmics, phenothiazines, tricyclic antidepressants, intravenous erythromycin), electrolyte abnormalities (hypocalcaemia and hypomagnesaemia), liquid protein diets and anorexia nervosa, and severe bradyarrhythmias. In acquired LQTS the arrhythmias are controlled by increasing the heart rate and eliminating pauses with the use of catecholamines or cardiac pacing, and also by correcting the underlying abnormality. In the congenital long QT syndromes, ventricular arrhythmias are precipitated by catecholamines (e.g. stress), and are suppressed by beta adrenergic blockers or excision of the left stellate ganglion. The electrophysiological mechanisms for the development of long QT syndromes include the abnormal

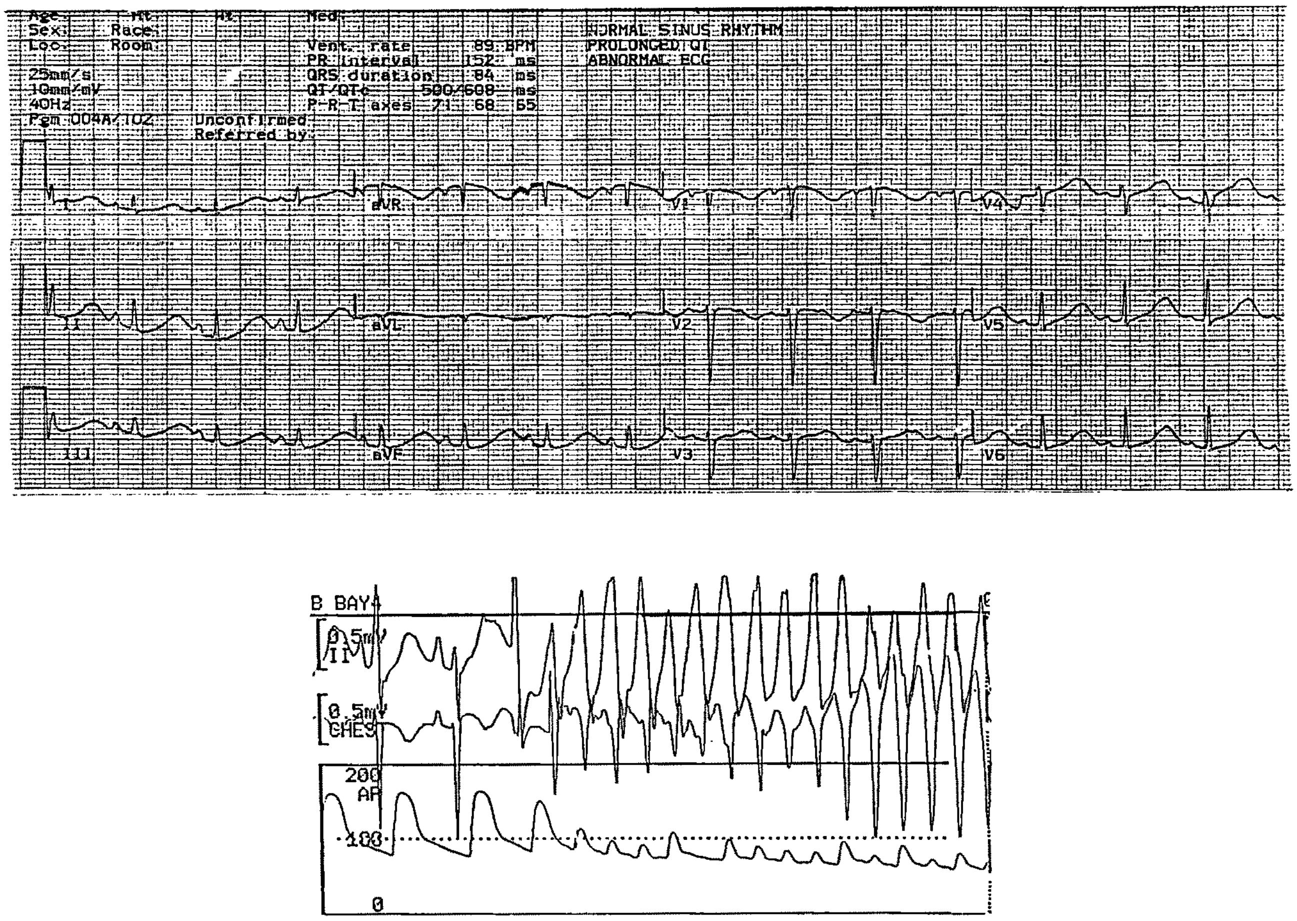

Fig. 1. Twelve lead ECG showing a prolonged QT interval and a monitor printout of the initiation of an episode of ventricular tachycardia.

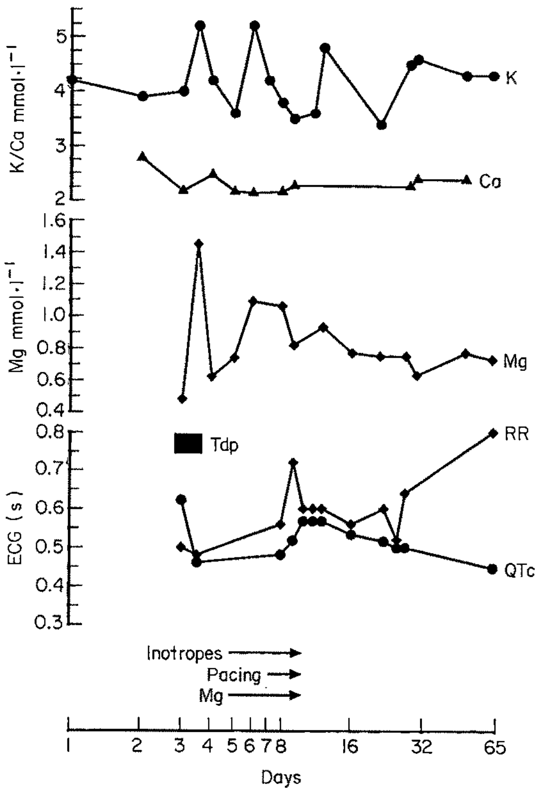

Fig. 2. Electrolyte levels and ECG intervals (y-axis) during the acute admission and subsequent follow-up (x-axis). Plasma potassium and calcium levels were essentially normal. The plasma' magnesium level was very low at the onset, rose to a peak after initial magnesium therapy but fell rapidly again necessitating prolonged therapy. The corrected QT interval (QTc) was markedly prolonged at onset but progressively returned to normal. This, however, showed a considerable lag compared with the plasma magnesium, and suggests that intracellular magnesium takes longer to be restored to normal. The RR intervals were short at the onset of the illness as a result of sinus tachycardia. K, potassium; Ca, calcium; Mg, magnesium; QTc, corrected QT interval; TdP, torsade de pointes tachycardia.

dispersion of refractoriness of the ventricular myocardium, which facilitates re-entrant tachycardia when an extrasystole occurs in the relative refractory period. These patients also have prominent after-depolarisations which can trigger the arrhythmia [4].

Magnesium reduces the slow inward L-type calcium current [6] and is responsible for the 'inward-rectifier' potassium current which maintains the normal resting potential. It also plays an integral role in the function of the sodium/potassium pump. Experimental studies show that it inhibits after-depolarisations [7, 8]. The role of magnesium therapy in ventricular arrhythmias, even without hypomagnesaemia, is now recognised [6, 7, 9, 10].

There are two sources of error in using serum Mg to assess magnesium deficiency [11]. Albumin binds 25–30% of the serum magnesium, and hypoalbuminaemia can produce a spuriously low magnesium level. This can be corrected for using the formula: Corrected Mg mmol.l^{-1} = Total Mg+0.05 (40− albumin g.l^{-1}) [12]. Serum contains only 0.3% of total body Mg, and intracellular Mg may be deficient in patients with normal serum magnesium levels. Magnesium deficiency can arise as a result of reduced intake or absorption; renal wastage (primary tubular disorders, drugs such as diuretics, aminoglycosides and digoxin, aldosteronism, hypoparathyroidism, hyperthyroidism, hypercalcaemia, osmotic diuresis and phosphate depletion); redistribution (e.g. insulin administration, catecholamine excess states and acute pancreatitis); excessive lactation; alcoholism and diabetic ketoacidosis [11]. Hypomagnaesemia has also been reported after massive blood transfusion in infants [13], and in animal studies [14], as a result of chelation by the citrate anticoagulant. Unrecognised hypomagnesaemia is common in patients undergoing critical care [15].

The severe hypomagnesaemia noted in our patient probably resulted from the massive blood transfusion. However the patient also received aminoglycoside and catecholamine therapy, but we feel that these were not significant aetiological factors, since they had only been administered for a few hours. The hypomagnesaemia resulted in an acquired long QT syndrome and life-threatening episodes of ventricular tachycardia. In this patient correction of the magnesium levels and overdrive pacing was life-saving. Hypomagnesaemia and magnesium deficiency should be considered in any patient who develops ventricular arrhythmias and has a prolonged QT interval. Hypomagnesaemia is a potential complication of massive blood transfusion and may have serious consequences.

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Anaesthesia, 1992, Volume 46, pages 128–130

CASE REPORT

Fatal pulmonary embolism following spinal anaesthesia for Caesarean section

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Summary

Pulmonary embolism remains one of the commonest causes of maternal death. Regional blockade is reported to decrease the incidence of postoperative thrombo-embolic disease. We describe a case in which a fatal pulmonary embolism followed an emergency Caesarean section for which the patient was given a spinal anaesthetic. We believe it to be the first time this has been reported.

Key words

Anaesthesia; obstetric.
Anaesthetic technique, regional; spinal.
Complications; pulmonary embolism.

The report on *Confidential enquiries into maternal deaths in the United Kingdom* 1985–87, shows that pulmonary embolism and hypertensive disorders of pregnancy remain the most common causes of maternal mortality [1]. Of the 13 postpartum deaths from pulmonary embolism, seven followed Caesarean section, suggesting that the risk after operative delivery is markedly increased compared with vaginal delivery.

Case history

An unmarried 29-year-old primiparous woman presented in spontaneous labour at 41 weeks' gestation. Her antenatal course had been uneventful and did not include any periods of immobilisation. She weighed 97.4 kg, smoked 10 cigarettes a day and had been normotensive throughout her pregnancy.

Labour initially progressed well, during which she required for analgesia one intramuscular injection of pethidine 100 mg and Entonox. After 9 h her labour failed to progress because of cephalopelvic disproportion and an emergency Caesarean section became necessary. There was no fetal distress.

The pre-operative haemoglobin level was 12 $g.dl^{-1}$ and baseline readings of heart rate 100 $beats.min^{-1}$, blood pressure 130/85 mmHg and an oxygen saturation of 96% when breathing air were obtained. After premedication with 30 ml of sodium citrate the patient's circulation was preloaded with 1500 ml compound sodium lactate solution. She was turned onto her right side and a 26 g spinal needle was inserted at the L_{2-3} interspace. Clear cerebrospinal fluid was obtained and 2.5 ml of hyperbaric 0.5% bupivacaine was injected into the subarachnoid space. A bolus dose of 9 mg of ephedrine was given intravenously as prophylaxis against hypotension.

Twelve minutes later the patient was delivered of a live female infant weighing 4.08 kg, with Apgar scores of 9 at 1 min and 10 at 5 min. The operation was complete 53 min after the spinal injection. There were no episodes of hypotension and the blood loss was estimated to be 400 ml. The patient recovered well, did not develop a headache and was sitting out of bed 20 h after the operation. She required three intramuscular injections of papaveretum 20 mg for analgesia in the first 24 h and nothing after that. On the second postoperative day her temperature was 37.9° C, but this settled spontaneously. It was noted that her calves were not tender. All observations remained normal, but owing to social circumstances she was not discharged until the eighth postoperative day.

The following day she was found dead at home. A postmortem revealed thromboses in the deep veins of the left leg and massive bilateral pulmonary emboli totally

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Table 1. Postpartum maternal deaths from pulmonary embolism, England and Wales 1970–87, compared with United Kingdom 1985–87. Adapted from the *Report on confidential enquiries into maternal deaths in the United Kingdom 1985–87*, London, 1991: HMSO.

		Deaths after vaginal delivery	Deaths after Caesarean section	Total
England and Wales	1970–72	22	15	37
	1973–75	13	6	19
	1976–78	20	9	29
	1979–81	4	7	11
	1982–84	4	12	16
	1985–87	5	3	8
United Kingdom	1985–87	6	7	13

occluding both main trunks of the pulmonary artery, with extension into all the peripheral vessels on the right side. There were no signs of thrombosis elsewhere and all other organs were normal. The cause of death was given by the coroner as massive bilateral pulmonary emboli due to deep vein thrombosis as a result of Caesarean section.

Discussion

Pregnancy is known to be a hypercoagulable state, with an increase in the clotting factors 1, 2, 7, 8, 9, 10 and 12 [2]. There is also a decrease in the level of antithrombin III [3] and of plasma fibrinolytic activity [4]. Although the hyperdynamic circulation of pregnancy means that the overall circulation time is reduced, venous return from the lower limbs is decreased as the pregnant uterus obstructs the inferior vena cava. Thus the risk of thrombo-embolic disease is increased sixfold compared with the nonpregnant state, and is further increased by previous thrombo-embolism, obesity, lupus anticoagulant, immobilisation and operative delivery [1].

Over the last decade clinical studies have suggested that anaesthesia may influence the development of postoperative deep venous thrombosis. Compared with general anaesthesia, subarachnoid block is associated with a significant decrease in the frequency of deep venous thrombosis (DVT) and pulmonary embolism following hip surgery [5–8]. There is similar evidence for extradural blockade and knee surgery [9]. This may be due to an increase in blood flow in the lower limbs [10] consequent upon vasodilatation, a decrease in platelet aggregation [11], enhanced fibrinolysis [12] and a decrease in blood viscosity [13]. The latter effect is a combination of the preload, the increased deformability of red cells and the vasodilation associated with subarachnoid blocks.

The reports on confidential enquiries into maternal death show that the number of postpartum deaths from pulmonary embolism has decreased since the 1970–72 triennium (Table 1). Since this time there has undoubtedly been an increase in the use of regional anaesthesia but no study has yet shown that either subarachnoid or extradural blockade is associated with a decrease in thrombo-embolic phenomena in obstetric practice. Part of the problem lies in the diagnosis of DVT which is notoriously difficult from clinical signs alone. Furthermore, as less than 10% of all pulmonary emboli are fatal [14], the report on maternal mortality will show only a small percentage of the total number of pulmonary emboli occurring in the pregnant population.

The methods commonly used for prophylaxis against DVT include low dose subcutaneous heparin, intermittent pneumatic compression of the calves, elasticated stockings, low dose aspirin and ankle supports. Only the first of these is of proven benefit in abdominal surgery [15]. In the case reported here the patient's ankles were supported away from the operating table.

Theoretically, subarachnoid anaesthesia may be of benefit as an additional prophylaxis against thrombo-embolism when used with subcutaneous heparin. Early mobility is desirable, and perhaps a smaller volume of local anaesthetic solution should be used, and thus give a less dense motor block. If a smaller volume is injected then it may be necessary to use a combination epidural/spinal technique so that an inadequate block could be improved upon. However, if this was necessary a dense motor block would probably be produced. An advantage of using a combined spinal and epidural technique would be in the provision of postoperative analgesia. In a recent study, it was shown that in a group of patients who received a continuous infusion of low dose bupivacaine for the 3 days following knee replacement, there was a decrease in the incidence of DVT [9]. These patients also wore elasticated stockings. Alternatively, the epidural injection of an opioid could be used for postoperative analgesia.

Once analgesia is adequate, mobilisation should be actively encouraged. The routine continuation of intravenous infusions may not be necessary in the patient who has had an uncomplicated Caesarean section with a regional anaesthetic. She could be given adequate oral fluids and, relieved of the infusion and drip stand, be more able to mobilise. All pregnant women are at risk of developing a DVT and those that have an operation have an increased risk. Should we be taking prophylactic measures in all women undergoing Caesarean section? Should low dose heparin with elasticated stockings become routine practice for such women?

In the case reported, the patient possessed three risk factors for the development of DVT: she was overweight, pregnant and underwent an operation. Although it is not supported by any studies, perhaps people in risk groups should be offered a regional anaesthetic with subcutaneous heparin, postoperative epidural analgesia and early oral fluids. However, as with this case and in the majority of postnatal women who die following pulmonary embolism, the in-hospital postdelivery course was unremarkable and contained no significant periods of immobilisation.

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Anaesthesia, 1992, Volume 47, pages 131–133

CASE REPORT

Anaesthesia in a patient with Noonan's syndrome and cardiomyopathy

A. M. CAMPBELL AND J. D. BOUSFIELD

Summary

A 5-year-old girl with Noonan's syndrome and a hypertrophic cardiomyopathy presented for myelography and subsequently, laminectomy. The anaesthetic management of the patient is described and the potential problems of the facial, cardiovascular and skeletal abnormalities associated with the condition are discussed.

Key words

Anaesthesia; paediatric.
Complications; Noonan's syndrome, cardiomyopathy.

Noonan's syndrome was first described by Noonan and Ehmke in 1963 [1, 2]. It is a rare clinical entity and represents the phenotype of Turner's syndrome with normal chromosome studies [3]. These patients have facial, cardiovascular and skeletal abnormalities which may pose problems to the anaesthetist during surgery [4]. The most common congenital cardiac lesion is pulmonary stenosis, either alone or in combination with a septal defect, which is usually atrial. In addition, it is now being recognised that many of these children also have a hypertrophic cardiomyopathy [5]. There have been no reports of general anaesthesia in this combination of Noonan's syndrome and cardiomyopathy. Therefore we describe the management of such a patient who required anaesthesia for two separate procedures.

Case history

A 5-year-old girl presented for investigation of a spastic diplegia. Family history was unavailable since she had been adopted at the age of 3 months, but she had appeared normal at birth. At 7 months she underwent pulmonary valvotomy for a dysplastic pulmonary valve. Heart muscle biopsy at that time showed evidence of a hypertrophic cardiomyopathy. Her growth was slow, remaining below the third centile, and at the age of 18 months a diagnosis of Noonan's syndrome was made.

At 3 years, following growth hormone injections, she was noted to walk on tip-toes. Over the next 2 years she developed increasing spasticity in both legs, and at 5 years she was admitted for CT scan and myelography under general anaesthesia.

The patient was an alert, friendly child who weighed 15 kg and whose height was 96 cm. She had features typical of Noonan's syndrome, namely hypertelorism, downward slanting eyes, low set ears, webbing of the neck and a low hairline. Physical examination of the chest showed a median sternotomy scar, a grade II/IV systolic murmur at the left sternal edge conducted to the aortic area, blood pressure of 90/40 mmHg and a heart rate of 80 beats.min^{-1}. Current medication consisted of propranolol 20 mg three times daily.

Echocardiography was reported to show evidence of hypertrophic cardiomyopathy and dynamic left ventricular outflow tract obstruction. The ventricular septal thickness was 2.5 cm while the posterior left ventricular wall thickness was 1.24 cm. Ventricular contraction, however, was within normal limits. Chest X ray showed left ventricular enlargement with increased pulmonary vascular markings. The electrocardiogram showed Q waves in leads II, III, aVF, V5 and V6, with left axis deviation and left ventricular hypertrophy.

She was premedicated 90 min pre-operatively with trimeprazine syrup 30 mg and droperidol 3 mg orally, and EMLA cream was applied to the backs of both hands. She was brought to the X ray department well sedated, and monitoring, which consisted of noninvasive blood pressure measurement, ECG and pulse oximeter, was applied. An intravenous infusion was started and prophylactic antibiotics, ampicillin 375 mg and gentamicin 60 mg, were administered. After infusion of 100 ml of gelofusine, anaesthesia was induced with thiopentone 50 mg and atracurium 7.5 mg. The lungs were manually ventilated with 35% oxygen in nitrous oxide, and after alfentanil 150 μg, the

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trachea was intubated easily with a 5.0 mm plain oral flexometallic (Mallinckrodt) tracheal tube. Anaesthesia was maintained with 35% oxygen in nitrous oxide and isoflurane 0.5%. The lungs were gently inflated by hand using a T-piece system, to maintain the end-tidal CO_2 between 4 and 5 kPa.

During induction of anaesthesia and throughout the procedure the systolic blood pressure remained between 80 and 100 mmHg, with a heart rate of 80 to 90 beats.min^{-1}. Oxygen saturation was stable at 96 to 98%. Neuromuscular blockade was reversed using neostigmine 0.75 mg and atropine 0.3 mg, and the trachea extubated. There were no problems postoperatively.

The myelogram showed tethering of the spinal cord by a filum at the level of the conus. Four weeks later the patient presented for lumbar laminectomy and division of filum.

For this procedure premedication consisted of trimeprazine 36 mg and droperidol 3.6 mg. Anaesthesia was induced in the manner described above, except that fentanyl 30 μg was given before intubation instead of alfentanil. After induction of anaesthesia, a right radial arterial line was inserted for direct blood pressure monitoring, and a right internal jugular venous line inserted for measurement of central venous pressure (CVP). In addition, an oesophageal stethoscope and temperature probe were passed into the lower third of the oesophagus. Skin temperature was also monitored. Neuromuscular blockade was monitored using a peripheral nerve stimulator. Anaesthesia was maintained with 35% oxygen in nitrous oxide and halothane 0.5–0.75%.

The patient was positioned prone on bolsters for surgery. Throughout the procedure, which lasted 90 min, the systolic blood pressure varied between 70 and 120 mmHg, heart rate remained stable at 80 beats.min^{-1} and the CVP was maintained between 4 and 6 mmHg. Intra-operative analgesia was provided by diamorphine infused at a rate of 0.3 μg.kg^{-1}.min^{-1} and this infusion was continued to provide postoperative analgesia.

After removal of the tracheal tube, the patient was transferred to the paediatric intensive care unit for monitoring overnight. The patient subsequently made an uneventful recovery and was discharged home 10 days postoperatively.

Discussion

The potential anaesthetic problems presented by a patient with Noonan's syndrome relate to impairment of cardiopulmonary function, the possibility of a difficult airway and the problem of technical difficulty with regional anaesthesia.

Noonan's syndrome is the XX or XY phenotype of Turner's syndrome, and is a distinct clinical entity [5, 7]. Patients with Noonan's syndrome have normal chromosomes, are fertile, are usually mentally retarded, and have right-sided cardiac lesions, usually pulmonary valve dysplasia. In addition, a large proportion have a hypertrophic cardiomyopathy, a fact which was not recognised in early descriptions of the condition.

There is a potential for airway difficulties in Noonan's syndrome because of the high palatal arch, dental malocclusion and webbing of the neck [8]. Although these features were present in our patient, they were not sufficiently prominent to warrant specific precautions, and indeed the trachea was intubated easily.

Regional anaesthesia may be technically difficult in Noonan's syndrome because of kyphoscoliosis, lumbar lordosis, and a relatively narrow spinal canal, which contains a normal sized spinal cord [4]. In our case, the age of the patient, the presence of a hypertrophic obstructive cardiomyopathy, and the nature of the surgery precluded the use of regional anaesthesia [9, 10], although it was noted that lumbar puncture for myelography was accomplished with ease.

In Noonan's syndrome 30–50% of the patients have pulmonary stenosis [4]. Right ventricular failure could be precipitated by an increase in pulmonary vascular resistance or excessive administration of intravenous fluids. Therefore, in addition to antibiotic prophylaxis for endocarditis, anaesthesia for patients with pulmonary stenosis should avoid hypoxia and include monitoring of CVP.

In the case described, the main problem facing the anaesthetist was that of provision of anaesthesia for a patient with hypertrophic obstructive cardiomyopathy, first of all in the X ray department and secondly for surgery in the prone position.

Hypertrophic cardiomyopathy is a primary disease of cardiac muscle characterised by a hypertrophic, nondilated left ventricle. Septal hypertrophy of at least 1.3 times the thickness of the ventricle wall is an invariable feature [11]. Left ventricular outflow tract obstruction is caused by the hypertrophied septum. The obstruction is dynamic in nature and may be reduced by increased ventricular volume, reduced contractility, and increased systemic vascular resistance [12]. Hypovolaemia, low peripheral vascular resistance and increased contractility due to sympathetic stimulation will lead to a worsening of the gradient across the left ventricular outflow tract.

Anaesthesia was directed towards minimising the pressure gradient across the left ventricular outflow tract obstruction. Beta-adrenergic blockade with propranolol was continued, and generous pre-operative medication with trimeprazine and droperidol reduced anxiety. Pre-induction expansion of the intravascular fluid volume may be important for maintaining intra-operative stroke volume and minimising the adverse effects of positive pressure ventilation.

Induction of anaesthesia was safely accomplished with thiopentone. Ketamine is not a good choice [11], since increases in myocardial contractility will accentuate obstruction to left ventricular outflow and reduce stroke volume. Administration of fentanyl before tracheal intubation was used to decrease pressor response to laryngoscopy.

Maintenance of anaesthesia was designed to produce mild depression of myocardial contractility and at the same time preserve systemic vascular resistance. Nitrous oxide combined with halothane was used, on the basis that it produces less of a reduction in systemic vascular resistance than enflurane or isoflurane [13].

Atracurium was used as a nondepolarising muscle relaxant, since it has minimal effect on the circulation although vecuronium would have been a reasonable alternative.

In addition to close monitoring of the ECG, invasive monitoring of arterial and right or left filling pressures is essential for all major surgery in order to detect hypotension and hypovolaemia and allow prompt replacement of blood loss and generous intravenous fluid administration.

Changes in filling volume, distending pressure of the left ventricle, heart rate and rhythm, and left ventricular afterload and contractility may adversely affect left ventricular outflow and decrease cardiac output. In addition, maintenance of sinus rhythm is critical since ventricular filling is dependent on left atrial contraction. Excessive positive pressure ventilation, which would have interfered with venous return, was avoided. For the same reason, particular care was taken over positioning the patient prone, since a reduction in venous return may cause a decrease in left ventricular volume and subsequent worsening of the outflow gradient.

In summary, several of the features of Noonan's syndrome may cause anaesthetic problems. The presence or absence of facial, cardiac or musculoskeletal abnormalities should be determined pre-operatively. Anaesthesia for patients with hypertrophic obstructive cardiomyopathy should avoid tachycardia, hypotension, and peripheral vasodilation, and maintain preload and afterload.

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CASE REPORT

Alfentanil increases intracranial pressure when intracranial compliance is low

E. MOSS

Summary

Intracranial pressure increases following the administration of alfentanil 1 mg are reported in five patients with suspected normal pressure hydrocephalus who were undergoing infusion of saline into a lateral ventricle to measure cerebrospinal fluid outflow resistance. The increase in intracranial pressure was accompanied by a fall in mean arterial pressure. These observations show that, when the intracranial compliance is reduced, alfentanil can cause considerable increases in intracranial pressure and decreases in cerebral perfusion pressure.

Key words

Intracranial pressure.
Analgesics; alfentanil.

Most opioid analgesics do not affect intracranial pressure (ICP) if the arterial carbon dioxide tension ($Pa\text{CO}_2$) is not allowed to increase. Phenoperidine has been reported to increase ICP [1, 2] in patients with head injury and more recently sufentanil has been shown to cause cerebral vasodilatation [3–5]. The effect of alfentanil on the cerebral circulation and ICP is uncertain.

In the author's hospital normal pressure hydrocephalus (NPH) is differentiated from senile cerebral atrophy by measurement of cerebrospinal fluid (CSF) outflow resistance. Saline is infused through one catheter inserted into a lateral ventricle through a frontal burr hole, and ICP is measured from another catheter sited in the lateral ventricle and connected to a suitably calibrated pressure transducer. At the end of the procedure it has been normal practice to administer alfentanil 1 mg to reduce the autonomic response to suture of the scalp. At this point saline is still being infused into the lateral ventricle producing the final ICP plateau on the pressure/flow graph. Observations of ICP and mean arterial pressure (MAP) in five patients are described below.

Case histories

Certain features were common to all five case histories. All the patients had measurements of CSF outflow resistance as described above. Temazepam was given for premedication and the patients were anaesthetised with fentanyl 100 μg, thiopentone, atracurium and nitrous oxide/oxygen supplemented with isoflurane 0.5 to 1%. Ventilation was adjusted to achieve an end-tidal carbon dioxide concentration of between 4.5 and 5 kPa. Throughout the measurement of CSF outflow resistance, and at the time of administration of the alfentanil, both ventilation and the inspired concentration of isoflurane were kept constant.

Case 1

A 71-year-old man presented with unsteadiness of gait and loss of memory for recent events. A computerised axial tomography (CT) scan showed dilated ventricles and the diagnosis of NPH was suggested by the radiologist. CSF outflow resistance was measured. When the test was complete, approximately 2 h after induction of anaesthesia, while the saline infusion into the lateral ventricle continued and the ICP remained stable, alfentanil 1 mg was given intravenously as a bolus to provide analgesia for suture of the scalp over the burr hole. The ICP increased from the plateau level of 20 mmHg to 26 mmHg after 3 min and the mean arterial pressure (MAP) (measured at 1 min intervals with a Datascope Accutorr 2 NIBP monitor) decreased from 110 mmHg to 104 mmHg. The pressures remained at these levels for 5 min until the saline infusion was discontinued and the ventricular catheters removed. The patient made a normal recovery from the anaesthetic. The CSF outflow resistance was normal so the diagnosis was senile

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cerebral atrophy and no further surgical treatment was indicated.

Case 2

A 74-year-old man presented with weakness in the legs and unsteady gait for 2 years with recent disorientation and impairment of memory. A CT scan showed dilated ventricles suggesting the possible diagnosis of NPH. CSF outflow resistance was measured. When the test was completed, approximately 2 h after induction of anaesthesia, while the saline infusion continued and ICP remained stable at 43 mmHg, alfentanil 1 mg was given as an intravenous bolus to provide analgesia for suture of the scalp. ICP increased from 43 to 53 mmHg and MAP decreased from 130 to 90 mmHg after 3 min. At this point the infusion of saline was rapidly terminated and CSF was drained from the ventricles to reduce ICP and restore cerebral perfusion pressure (CPP) to normal levels. When surgery was complete the patient recovered normally from the anaesthetic. The CSF outflow resistance was raised and the diagnosis of NPH was made. A ventriculoperitoneal shunt was performed at a later date with subsequent improvement in the patient's condition.

Case 3

A 69-year-old woman presented with a 1 year history of progressive ataxia and increasing disturbance of speech. She gave a 20 year history of ischaemic heart disease and took sublingual glyceryl trinitrate when required. A CT scan demonstrated enlarged lateral ventricles suggesting a possible diagnosis of NPH and CSF outflow resistance was measured. At the same stage of the procedure as in the first two cases alfentanil 1 mg was administered. ICP increased from 23 to 28 mmHg 2 min after the administration of alfentanil and decreased to 25 mmHg over the next 3 min. MAP decreased from 75 to 65 mmHg at 3 min and increased to 72 mmHg over the next 2 min. The test confirmed NPH and a ventriculoperitoneal shunt was performed one week later.

Case 4

A 61-year-old man presented with a 1 year history of unsteadiness on his feet and minimal disturbance of memory. A CT scan showed enlarged lateral ventricles suggesting a possible diagnosis of NPH and CSF outflow resistance was measured. At the same stage of the procedure as in the first three patients alfentanil 1 mg was administered. ICP increased from 41 to 47 mmHg after 2 min and to 62 mmHg after 3 min, at which point the saline infusion was stopped and the lateral ventricles drained to reduce ICP and restore CPP. Mean arterial pressure decreased from 107 to 76 mmHg at 2 min after the administration of alfentanil. The test confirmed NPH but, because there was some improvement in the ataxia after the study, the patient was observed with a view to performing a ventriculoperitoneal shunt in the future if necessary.

Case 5

A 64-year-old woman presented with ataxia, stress incontinence and poor memory. A CT scan showed dilated lateral ventricles suggesting a possible diagnosis of NPH and CSF outflow resistance was measured. At the same stage of the procedure as in the other cases, and for the same reasons, alfentanil 1 mg was administered. ICP increased from 30 mmHg to 46 mmHg after 2 min and 54 mmHg after 3 min. MAP decreased from 100 to 70 mmHg after 2 min and 74 mmHg after 3 min. At this point the saline infusion was stopped and the lateral ventricles drained to reduce ICP. The test confirmed NPH and a ventriculoperitoneal shunt was performed one week later.

Discussion

CSF outflow resistance can be calculated by measuring ICP whilst infusing saline into a lateral ventricle at several different rates. The ICP plateaus at each infusion rate and this value for ICP is used in the calculation of CSF outflow resistance. For ICP to rise the compensatory mechanisms for reducing ICP must have been overcome and intracranial compliance must be reduced. Because it is important that the concentration of anaesthetic agents and the ventilation are not altered during the measurements, the analgesia for closing the scalp wound is not given until the measurements are complete.

The pharmacokinetic properties of alfentanil make it useful for providing intense analgesia for a short period of surgical stimulation without producing postoperative respiratory depression. This was the rationale for using it in these patients who tend to become hypertensive during suture of the scalp if analgesia is inadequate. However, the observations in these patients show that 1 mg bolus doses of alfentanil can cause large increases in ICP in patients with reduced intracranial compliance and raised ICP. The patients are reported in the order in which they presented so that, although ICP increased in each of the first three patients, a dramatic increase requiring immediate intervention to reduce ICP was seen in only one patient, and could conceivably have been due to a response peculiar to that patient. It was only when similar large increases in ICP occurred in the last two patients that it became clear that they were caused by the alfentanil and that this drug should be avoided when compliance is reduced and ICP high.

An increase in ICP following bolus intravenous administration of alfentanil has been reported before by Marx and his colleagues [6], and these authors suggested that alfentanil may be a cerebral vasodilator. The increase in ICP in these patients was so rapid that it must have been due to cerebral vasodilatation. The $Pa\text{CO}_2$ remained constant so changes in $Pa\text{CO}_2$ cannot explain the increase in ICP. The cerebral vasodilatation may have been due to a direct effect on the cerebral vessels or could have been secondary to a fall in arterial pressure and CPP leading to a compensatory decrease in cerebral vascular resistance. Rapid infusion of alfentanil, rather than bolus injection, may have less effect on the arterial pressure and thus any compensatory vasodilatation and increase in ICP. However, if alfentanil has a direct vasodilator effect on the cerebral vessels, rapid infusion will still cause an increase in ICP.

In cases 2, 4 and 5 there was a rapid decrease in MAP of between 30 and 40 mmHg and these patients had large increases in ICP and decreases in CPP necessitating rapid reduction of ICP by drainage of CSF. In these patients the large increase in ICP was probably partly due to the reduction in MAP causing a compensatory decrease in cerebral vascular resistance in an attempt to maintain cerebral blood flow (CBF). The cerebral vasodilatation would cause an increase in cerebral blood volume which in turn would increase ICP. In cases 1 and 3 the reductions in MAP were small so it is unlikely that this was the cause of the cerebral vasodilatation and increase in ICP. The more likely explanation in these cases is a direct vasodilator effect on the cerebral vessels. Increases in lumbar CSF pressure have been reported following alfentanil in patients with supratentorial tumours when phenylephrine was used to keep them normotensive [7], which supports the contention that alfentanil has a direct vasodilator effect.

Although most opioid analgesics have no effect on CBF and ICP if respiratory depression is avoided, there are exceptions. Phenoperidine has been associated with increases in ICP in patients with head injury [1, 2] and sufentanil is known to be a cerebral vasodilator causing increases in CBF [3–5] and ICP [6, 8]. Of the opioid analgesics currently available, fentanyl appears to be the most suitable for use in anaesthesia in patients with raised ICP because it has no effect on CBF [3] and ICP [6, 7, 10] and has a short duration of action.

As a result of the observations in these patients, the author now avoids alfentanil until the saline infusion has been stopped and the ICP has returned to near normal. This will prevent major increases in ICP following the administration of alfentanil in these patients. However, patients with reduced intracranial compliance due to cerebral tumour, cerebral trauma causing cerebral oedema or intracranial haematomata may show a similar response to bolus doses of alfentanil. This response would be more dangerous in such patients because rapid reduction of ICP by CSF drainage is not usually possible. Therefore, bolus doses of alfentanil are best avoided in patients with reduced intracranial compliance and raised ICP.

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CASE REPORT

Anaesthetic problems in a child with ectrodactyly, ectodermal dysplasia and cleft lip/palate

The EEC syndrome

A. MIZUSHIMA AND M. SATOYOSHI

Summary

The EEC syndrome is a congenital anomaly complex associated with ectrodactyly, ectodermal dysplasia, and cleft lip and palate. We present a patient with the complete form of this syndrome who had undergone eight operations in childhood. The main problems encountered by the anaesthetists were malnutrition, difficulty with control of body temperature related to hypohidrosis and persistent infection of the respiratory tract.

Key words

Anaesthesia; paediatric.
Complications; EEC syndrome (ectrodactyly, ectodermal dysplasia, cleft lip and palate), hypohidrosis.

The EEC syndrome is a congenital anomaly complex characterised by ectrodactyly, ectodermal dysplasia, and cleft lip and palate [1, 2]. Recently, a high incidence of genitourinary anomalies, including cryptorchidism, hypospadias and hydronephrosis, have been reported in addition [3, 4]. Affected patients frequently require repeated surgery, especially in childhood. Although these abnormalities must complicate the peri-operative course, very little has been published about the anaesthetic management. We describe a patient who had the complete form of the EEC syndrome which included severe malnutrition, chronic respiratory tract infection and difficulty with body temperature control. The problems of the anaesthetic management are discussed.

Case history

A 2.65 kg full term female infant was born after an uncomplicated prenatal course. There was no family history of congenital malformations or parental consanguinity. At birth, the following abnormalities were noted; split hands and feet, alopecia totalis, hypopigmentation, hypoplasia of lacrimal ducts, low set and deformed ears, burn-like skin erosions over the body, and complete cleft lip and palate. Chromosomal analysis revealed a normal 46 XX pattern.

At 18 months, the patient was transferred to our hospital for surgical treatment. She was severely malnourished and weighed 7.2 kg. Her skin was thin and dry and she had a large ulcer on her head. Chronic blepharitis, keratoconjunctivitis, and purulent otorrhoea were present. The tongue was large, and the lingual and oral mucosa were dry and covered with thick white patches. She could not control her head and tended to lie prone. On auscultation of the chest, widespread coarse crepitations were heard. The sputum was thick, and chest X ray showed a generalised increase in density over the lung fields. There were wide fluctuations in body temperature.

The operations and their anaesthetic management are summarized in Table 1 and peri-operative complications in Table 2.

Operation 1

Before the corrective surgery, a gastrostomy was needed for feeding. No premedication was given. On arrival in the operating theatre, the patient was in an excited state. Monitors consisted of precordial stethoscope, electrocardiogram, indirect arterial pressure, and rectal temperature. After pre-oxygenation, anaesthesia was induced with halothane 2% and nitrous oxide 50% in oxygen with spontaneous respiration. Tracheal intubation was accomplished easily without a neuromuscular relaxant and ventilation was controlled artificially by hand. Frequent tracheal suction was needed because of copious thick secretions. The rectal temperature increased to 38°C and topical cooling with alcohol was started. Suxamethonium 15 mg was given in divided doses during the surgical procedure. There was an abnormal tendency to bleed from the oper-

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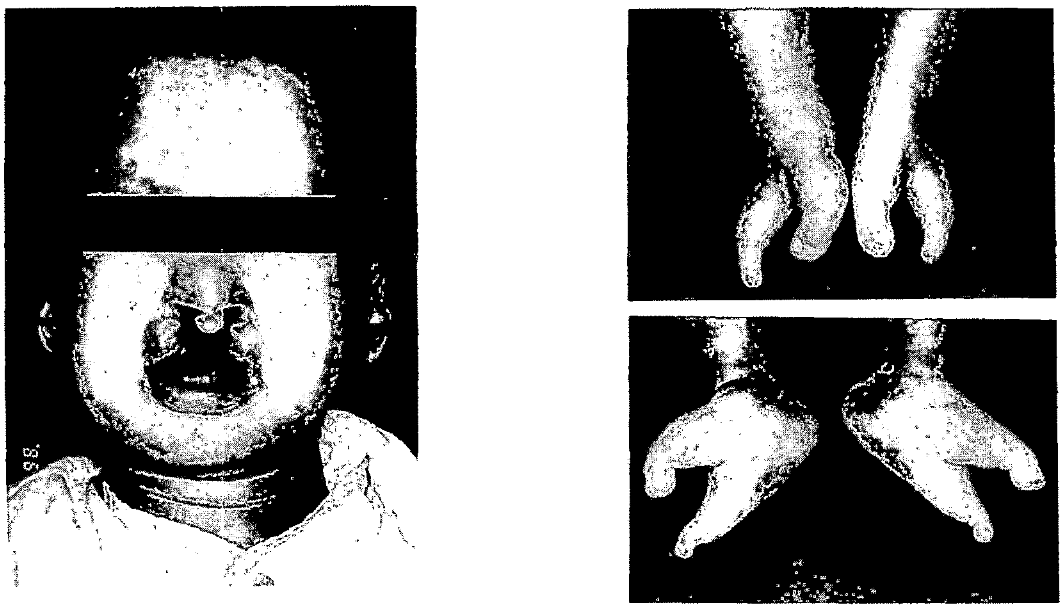

Fig. 1. Clinical appearance on admission. *Left*: dry and thin skin with large ulcer of the head, absence of eyebrows and eyelashes, blepharitis, keratoconjunctivitis, low-set and deformed ears, broad nose, and bilateral complete cleft lip and palate. *Top right*: typical split hands deformity. *Bottom right*: typical split feet deformity. These photographs are published with the consent of the child's guardian and the ethics board of Juntendo University School of Medicine.

ating field. After tracheal lavage, the tube was removed. The recovery period was uneventful. Histological examination of a skin biopsy confirmed hypoplasia of the sweat glands.

Operation 2

After 4 months of nutritional support, repair of the cleft lip and skin grafting to a large ulcer of the head were performed. Diazepam syrup 5 mg was given via the gastrostomy 2 h before operation, and this time the patient was quite calm on arrival in the operating theatre. Monitoring, which was the same as for the first operation with the addition of pulse oximetry, was begun before induction. Anaesthesia was induced with halothane 1.5% and thiopentone 25 mg and the trachea was intubated without a neuromuscular relaxant. Anaesthesia was maintained with enflurane 1–2%. An external incision was needed to insert the urinary catheter because of vulval hypoplasia. When the rectal temperature increased to 37.8°C, body surface cooling was started with alcohol and a cooling mat. However, rectal temperature decreased so rapidly to 34.8°C that cooling was discontinued and the temperature subsequently rose to 36°C without special treatment. Red cell concentrate 60 ml was transfused because of a pre-operative anaemia. Frequent tracheal suction and bronchial lavage were needed to remove the copious secretions. The recovery from anaesthesia was smooth except for transient shivering and peripheral cyanosis although the oxygen saturation was greater than 95% throughout the operation. For 3 days after surgery the axillary temperature was difficult to control and fluctuated from 36.2°C to 39.6°C.

Operation 3

After correction of the cleft lip, repair of the cleft palate was performed. Anaesthetic procedures were identical to those in operation 2. This time, with careful management, the intra-operative rectal temperature was maintained between 36.1 and 37.4°C.

Table 1. Operations and anaesthetic management.

No.	Age	Weight (kg)	Operation	Premedication	Induction*	Maintenance*	Neuromuscular blocker
1	1 year 7 months	7.8	Gastrostomy	Nil	Halothane	Halothane	Suxamethonium
2	1 year 10 months	8.5	Surgical repair of cleft lip skin grafting of the head ulcer‡	Diazepam	Halothane thiopentone	Enflurane	Nil
3	2 years 2 months	10.6	Surgical repair of cleft palate‡	Diazepam	Halothane	Enflurane	Nil
4	2 years 7 months	10.0	Left keratoplasty†	Nil	Halothane	Halothane	Nil
5	2 years 11 months	11.0	Right keratoplasty†	Nil	Enflurane	Enflurane	Pancuronium
6	3 years 3 months	11.8	Left keratoplasty†	Nil	Enflurane	Enflurane	Pancuronium§
7	3 years 8 months	12.5	Surgical repair of the split-feet skin grafting of the head ulcer‡	Nil	Halothane thiopentone	Enflurane	Pancuronium§
8	4 years 4 months	10.4	Closure of gastrostoma	Diazepam	Halothane thiopentone	Halothane	Vecuronium§

*, with nitrous oxide in oxygen; †, emergency operation; ‡, adrenaline infiltration in the surgical fields; §, reversed with atropine and neostigmine after operation.

Table 2. Peri-operative complications.

No.	Pre-operation	Intra-operation	Postoperation
1	Severe malnutrition anaemia	Copious tracheal secretions bleeding tendency	Hyperthermia*
2	Anaemia	Copious tracheal secretions hypothermia†, shivering peripheral cyanosis	Hyperthermia
3	Leukocytosis	Copious tracheal secretions	Hyperthermia
4		Copious tracheal secretions hypothermia	
5–6		Copious tracheal secretions	
7	Leukocytosis	Copious tracheal secretions hypothermia	Severe diarrhoea hyperthermia
8	Anaemia	Copious tracheal secretions	Hypothermia

*; above 38.5°C, †; below 36.0°C.

Operation 4–6

In spite of ophthalmological care, emergency keratoplasties were required for perforations of the cornea. Infection of the respiratory tract, with thick secretions, persisted. Again, body temperature showed only relatively small fluctuations.

Operation 7

When the patient was able to stand up, surgical repair of the feet was required. At the same time, skin grafting was performed for a nonhealing ulcer of the head. Severe diarrhoea occurred after surgery. She was discharged after the seventh operation but had to be readmitted because of weight loss to 9.4 kg as a result of feeding problems.

Operation 8

Feeding improved, therefore the gastrostomy was closed before the patient finally left hospital.

At the time of discharge at the age of 4 years, her developmental age was estimated to be about 15 months and she had severe impairment of vision and hearing.

Discussion

The EEC syndrome was first described in 1970 [1]. At least 180 patients have been described subsequently, of whom there were 70 with the complete triad [3, 5]. Autosomal dominant inheritance has been suggested in some cases and sporadic appearance in others [2, 5–7]. This patient had a normal chromosomal pattern and no family history of congenital anomaly, therefore she was considered to be a sporadic case.

The following problems were encountered in our patient.

(1) *Ectrodactyly*: the most characteristic feature of the syndrome is lobster claw deformity. However, variable degrees of abnormalities such as syndactyly and clinodactyly are included in the incomplete form, and may require repeated surgery. In our patient, correction of abnormalities of the feet was undertaken to allow shoes to be fitted.

(2) *Ectodermal dysplasia*: this affects the skin, hair, teeth, eyes, ears, mucosae, sweat glands, and central nervous system and may be the predominant clinical abnormality.

(a) *Temperature control*: disordered control of body temperature was noticed throughout the course of treatment, and resulted from impaired heat loss with hypohidrosis secondary to hypoplasia of the sweat glands. Immaturity of central temperature control mechanisms may have contributed to excessive cooling during anaesthesia and the wide fluctuations in temperature seen in the ward. Atropine as premedication was avoided in all operations, to prevent exacerbation of hypohidrosis and heat retention.

(b) *Respiratory tract infection*: chronic infection has persisted even after surgical repair of cleft lip and palate. Chest physiotherapy is important to reduce intra- and postoperative respiratory complications. Tracheal intubation and controlled ventilation with humidification was essential in all operations to cope with the thick, copious secretions. Repeated tracheal suction, bronchial lavage and postural drainage were required.

(c) *Skin fragility*: the combination of malnutrition and a thin, delicate, fair skin resulted in ulcers which failed to heal with conservative treatment. Extreme care is required peri-operatively to prevent further damage.

(d) *Eye complications*: chronic blepharitis, conjunctivitis, and keratitis, are common features of this syndrome and result from decreased tear formation. Intra-operative eye protection is essential and in our case the eyes were protected with ointment.

(e) *CNS involvement*: mental retardation in 8% and hearing impairment in 13% of the patients with EEC syndrome has been reported [3]. Our patient suffered from both complications.

(3) *Cleft lip and palate*: these cause feeding difficulties, repeated respiratory tract infection, and airway management problems. Difficult tracheal intubation may be associated with this syndrome but in this case, intubation was facilitated by the use of a handmade gauze pack to bridge the cleft.

(4) *Malnutrition* and *anaemia* were major problems which resulted from poor oral intake and loss of protein from skin ulcers. On admission, the patient's weight was below the third percentile for her age and she had a low serum iron. The feeding gastrostomy was required for 33 months, in addition to repeated blood transfusion.

(5) *Genitourinary anomalies* have been reported as a major feature of this uncommon syndrome [4, 5], although in our case, no renal abnormality was noted. However, the presence of vulval hypoplasia meant that a perineal incision was needed to insert the urinary catheter.

Syndromes which are associated with ectodermal dysplasia have multiple complications and manifest themselves in many different ways.

Although patients with the full EEC syndrome are easy to diagnose, there are a number of related syndromes in which some of the features are absent.

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CASE REPORT

Rapidly progressive laryngeal oedema associated with pregnancy-aggravated hypertension

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Summary

We report a patient with pregnancy-aggravated hypertension who developed rapid progression of laryngeal oedema intra-operatively and in whom airway obstruction occurred immediately following extubation. There were no pre-operative signs to indicate potential airway problems.

Key words

Anaesthesia, obstetric.
Anaesthesia, complications; laryngeal oedema.
Obstetrics, complications; pregnancy-induced hypertension.

Laryngeal oedema in association with gestational hypertension is a rare but potentially serious complication. The majority of cases reported in the literature have obvious premonitory signs such as facial or generalised oedema which enable the anaesthetist to anticipate airway problems prior to induction of anaesthesia. Such was not the case in the patient described below.

Case history

A 40-year-old black woman, weighing 102 kg, presented to her general practitioner complaining of frontal headaches and blurring of vision. On examination she was 36 weeks pregnant, had a blood pressure of 190/120 mmHg and proteinuria. Her past obstetrical history showed that she had had five normal vaginal deliveries followed by a Caesarean section at 28 weeks for severe gestational hypertension. Following the birth of her last child, one year earlier, therapy with antihypertensive drugs was commenced, but she had defaulted medication for the past 6 months.

Her general practitioner referred her to the local clinic where her blood pressure was recorded as 220/150 mmHg. She was given 10 mg diazepam intramuscularly at 1250 h and was transferred to the obstetric unit at our institution. On admission her blood pressure remained elevated at 220/150 mmHg, her pulse rate was 104 beats.min^{-1}, she had ketones (+ + +) in the urine and her haemoglobin was 10.5 g.dl^{-1}. A central venous pressure (CVP) line was inserted and rehydration with crystalloid (Plasmalyte L) to a CVP of 6 cmH$_2$O begun. She was also given methyldopa 1 g orally followed by 500 mg 6 hourly to control her hypertension. Biochemical investigation on admission showed the following: Na$^+$ 130 mmol.l^{-1}, K$^+$3.8 mmol.l^{-1}, Cl$^-$ 107 mmol.l^{-1}, bicarbonate 18.8 mmol.l^{-1}, urea 3.5 mmol.l^{-1}, creatinine 138 μg.l^{-1}, urea/creatinine ratio 25, anion gap 8.8. Liver function tests showed: total protein 56 g.l^{-1}, albumin 33 g.l^{-1}, globulin 23 g.l^{-1}, bilirubin 7 μmol.l^{-1}, alkaline phosphatase 318 μmol.l^{-1}, AST 11 μmol.l^{-1}, GGT 8 μmol.l^{-1}. Coagulation studies were within normal limits: prothrombin time 14.2 s (control 14.1 s), international normalised ratio 1.00, partial thromboplastin time 28.6 s (control 25–35 s), fibrinogen titre 2.56 g.l^{-1} (normal 1.28–2.5 g.l^{-1}), platelet count 318 × 10^9.l^{-1}. At 1815 h her blood pressure remained elevated and 200 mg phenobarbitone was administered intramuscularly.

At 2200 h her blood pressure was 170/100 mmHg and the cardiotocogram (CTG) showed a single deceleration. Pethidine 100 mg and promazine 50 mg were given intramuscularly at this time and hydralazine 30 mg orally 8-hourly was added to her therapy. At 2330 h her blood pressure had fallen to 110/70 mmHg and at 0025 h on the day after admission she was transferred to the ward; her blood pressure was to be checked every 4 h. On the third day of admission her blood pressure again rose to 190/130 mmHg despite aldomet 1 g.day^{-1} and hydralazine

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90 mg.day^{-1} and she was referred for Caesarean section and tubal ligation.

On arrival in the operating room, 30 ml 0.3 M sodium citrate was administered orally. Her blood pressure was noted to be 210/135 mmHg and the CVP to be 6 cmH_2O. A left radial artery cannula was inserted. Hydralazine was administered intravenously to a total dose of 12.5 mg until her blood pressure was controlled at 160/90 mmHg. Following pre-oxygenation and intravenous metoclopramide 10 mg, a rapid sequence induction using alfentanil 2 mg, etomidate 20 mg and suxamethonium 100 mg was performed. Cricoid pressure was applied when consciousness was lost. At laryngoscopy no glottic oedema was noted and a size 8 tracheal tube (Portex PVC) was inserted without difficulty. The intra-operative course was uneventful; the blood pressure remained well controlled and the CVP stable. Anaesthesia was maintained intra-operatively with N_2O 50% in oxygen and 1% enflurane. An additional 100 μg of fentanyl was administered immediately after delivery and the whole surgical procedure was completed in 30 min under the single initial dose of suxamethonium. A live male infant weighing 2.7 kg was delivered with some difficulty and the Apgar scores at 1 and 5 min were 6 and 10 respectively.

At termination of surgery the patient was awakened and when fully awake and breathing well her trachea was extubated. Immediately following extubation it was noted that she had difficulty breathing and that she was becoming cyanosed. Laryngoscopy was performed at once and gross oedema of the glottis was apparent. Intubation with a size 5.5 tracheal tube was undertaken with difficulty and thereafter the patient's condition improved. Arterial blood gas analysis at this time showed pH 7.25, $Pa\text{CO}_2$ 5.52 kPa, $Pa\text{O}_2$ 13.5 kPa, HCO_3^- −18.1, BE −8.7, $Sp\text{O}_2$ 96.7%. The patient was given intravenous diazepam 10 mg, papaveretum 20 mg, hydrocortisone 500 mg and was transferred to the intensive care unit (ICU). The CVP on admission to the ICU was 0 cmH_2O. Blood pressure was controlled with a hydralazine infusion, sedation was produced by paraveretum as required and the patient was allowed to breathe spontaneously on a 'T-piece'. The following day the vocal cords were re-examined under direct laryngoscopy and as no oedema was observed the patient was extubated. The patient made an uneventful recovery in the ward and was discharged home 7 days after delivery, on antihypertensive therapy.

Discussion

This case documents the rapidity with which airway problems associated with pregnancy-aggravated hypertension (PAH) can progress and highlights the need to consider epidural anaesthesia whenever possible. The anaesthetist was caught unawares, because although the patient had severe PAH there were no warning signs such as facial oedema, enlarged tongue, voice change or stridor. The development of the laryngeal oedema was thus both rapid and unexpected.

Laryngeal oedema associated with gestational hypertension is a rare but potentially serious complication and was first reported in 1977 [1]. Since the first report a further 13 cases of laryngeal oedema at delivery have been recorded [2–11], but not all had associated hypertension. Where hypertension was not a feature, factors implicated in the aetiology included raised venous pressure resulting from the sustained effort of a prolonged labour [2], and fluid overload in conjunction with the antidiuretic properties of oxytocin [4, 5]. The development of rapid weight gain in late pregnancy or an upper respiratory tract infection have also been described as precipitating factors [6, 8]. Many of the cases reported in both hypertensive and normotensive patients have obvious facial or generalised oedema, so that possible airway oedema can be anticipated. Stridor is very uncommon and appears to indicate an associated upper respiratory tract infection [8]. The unusual features of this case are that there were no pre-operative pointers to the likelihood of laryngeal oedema and that upon initial laryngoscopy and intubation no oedema was noted. To our knowledge, the rapid intra-operative development of glottic oedema has not been reported before. Intra-operative fluid overloading is not throught to be a likely cause of the sudden development of oedema; colloid osmotic pressure is also unlikely to be a problem as the pre-operative albumin was only just below the normal range. However, a possible cause is inadequate relaxation as only one dose of suxamethonium was used during the procedure, but as the patient was not straining against the ventilator this seems unlikely. A further possibility is that the size 8 tracheal tube was too large for a potentially oedematous airway; it is strongly recommended that a smaller than normal sized tracheal tube be used and that airway instrumentation during intubation be kept to a minimum.

Postextubation laryngeal oedema has been reported three times previously. Keeri-Szanto described a case of progressive airway obstruction developing over 3 days, and localised to the subglottic area, in a patient who was intubated for a period of 12 h [3]. The airway obstruction progressed to the point where tracheostomy was required. In another case, Hein reported a cardiorespiratory arrest in the postoperative period shortly after extubation [9]. In this latter case, moderate laryngeal oedema and swelling of the false cords was noted on intubation and the author felt that the combination of a prolonged labour with slow progress, an upper respiratory tract infection and pregnancy-induced hypertension combined to cause the airway obstruction which developed over 1 h. The third case developed oedema 4 h postoperatively and was associated with excessive peri-operative fluid administration in the presence of oligaemia [11].

As laryngeal oedema may develop during the intra-operative period, anaesthetists must take great care when extubating patients with gestational hypertension. We advise anaesthetists to follow the practice of Potgieter and Hammond who suggested that the cuff be deflated and the tracheal tube lumen occluded digitally to assess whether the patient is able to breathe around the tube [12]. Air moving past the tube will confirm that the airway is patent, at least to the diameter of the tracheal tube. Patients with premonitory signs of oedema before anaesthesia require comprehensive pre-anaesthetic airway evaluation, either by gentle direct laryngoscopy as suggested by Heller [10] or preferably, if available, by fibreoptic evaluation.

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APPARATUS

A portable mouth pressure meter

P. E. M. SMITH AND R. A. ROYALL

Summary

The design and function of a device for bedside measurement of maximum static respiratory pressures is reported. The ability to measure maximum inspiratory and expiratory pressures allows a simple means of monitoring respiratory muscle weakness in both acute and chronic conditions.

Key words

Respiratory function tests; maximum expiratory pressure, maximum inspiratory pressure.

The assessment of respiratory muscle function is essential in the monitoring of acute respiratory muscle weakness and has become increasingly important in chronic neuromuscular disease with the wider application of long-term assisted ventilation [1]. The measurement of maximum respiratory pressures gives the most directly available, noninvasive assessment of respiratory muscle strength [2]. Maximum static inspiratory and expiratory mouth pressures are reliable, reproducible and sensitive to minor degrees of respiratory weakness [3], and provide a useful addition to the measurement of vital capacity and of arterial blood gas tensions in this situation. Wider application of their measurement has been hindered by the cumbersome nature of available equipment.

We have developed a lightweight, compact, hand-held device for bedside measurement and display of maximum static inspiratory and expiratory pressures.

Apparatus

The device (Fig. 1) is housed in a low-profile, hand-held plastic case measuring approximately $16 \times 8 \times 2.5$ cm and weighing about 200 g (including battery). The display provides an analogue bar graph of current pressure, and a digital display of the maximum pressure achieved. The range of pressure displayed is between -150 and $+150$ cmH_2O; accuracy is better than 3% with an additional zero offset of less than 3 cmH_2O. The device automatically measures expiratory or inspiratory pressures without operator intervention. There is only one control, a push switch which turns the device on and resets the maximum pressure display. The device automatically switches off 4 min after the display is last reset to prevent accidental

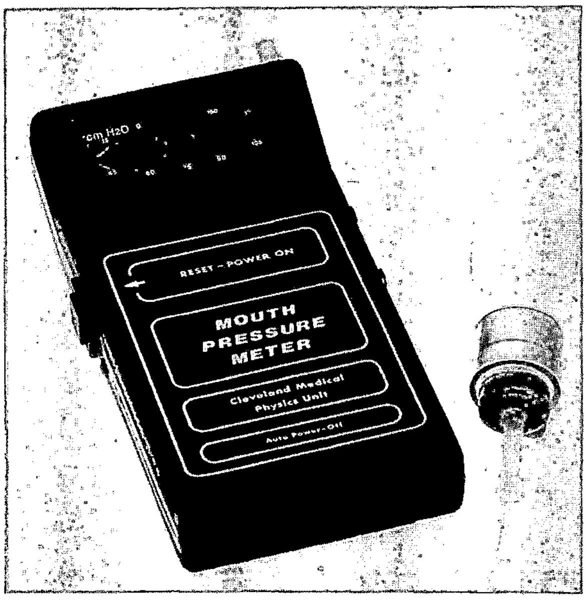

Fig. 1. The portable mouth pressure meter.

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flattening of the battery; the PP3-sized battery provides more than 100 h of life. The Luer lock pressure input is connected to the mouthpiece holder by a standard disposable manometer line. The mouthpiece, also disposable, has a standard 20 mm taper connection, and thus, all patient parts are either disposable or cold sterilisable. To prevent glottic closure during maximal manoeuvres, a pinhole leak is incorporated into the mouthpiece holder.

Static mouth pressures are measured as previously described [2,4] using a mouthpiece and noseclip (or a well-fitting facemask) with the patient verbally encouraged to produce maximum effort. Expiratory pressures are measured traditionally from full inspiration, and inspiratory pressures after full expiration; alternatively, both may be measured at functional residual capacity.

Discussion

The device is simple to use for both patient and clinician and, as with similar but less compact equipment, provides a more direct and sensitive assessment of respiratory muscle function than vital capacity, blood gas tensions and peak expiratory flow rate. A range of normal values of respiratory mouth pressures is available for adults and children [4,5].* We hope that the availability of this equipment will encourage more widespread application of maximum respiratory pressure measurement in the assessment of neuromuscular disease.

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* A guide to normal adult maximum static mouth pressures (cmH_2O) may be obtained using the equations derived by Wilson *et al.* [4] as follows: Inspiratory: $142-(1.03\times \text{age})$ for males and $(0.71\times \text{height in cm})-43$ for females. Expiratory: $180-(0.91\times \text{age})$ for males and $3.5+(0.55\times \text{height in cm})$ for females.

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Forum

2% propofol for sedation in the intensive care unit

A feasibility study

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Summary

A 2% solution of propofol has been compared with the 1% formulation for sedation in patients whose lungs were being mechanically ventilated in an intensive care unit following coronary artery bypass surgery. There were no significant differences in the amount of propofol used in the two groups, the rate of propofol infusion or the number of changes made to the infusion rate to maintain the desired level of sedation. Recovery times and times to tracheal extubation were similar. The mean heart rates of those receiving 2% propofol were significantly higher throughout the period of the study for no apparent reason. Propofol 2% was found to be safe, easy to administer and a practical alternative to the 1% solution for sedating cardiac surgical patients.

Key words

Anaesthetics, intravenous; propofol.
Intensive care.

A continuous infusion of a 1% solution of propofol is widely used as a sedative agent in the intensive care unit. Its pharmacokinetic properties allow an easily controllable level of sedation [1] and rapid recovery when administration is stopped. Recovery from sedation is significantly more rapid when compared with techniques using a benzodiazepine and an opioid [2–4]. Although originally formulated in Cremophor EL, the drug is now presented as an emulsion containing soya bean oil and purified egg phosphatide. Comment has been made that critically ill patients have altered metabolic and enzyme systems such that they might not be able to handle an excessive fat load that would be given during prolonged infusions of propofol.

A formulation containing 2% propofol has recently been prepared, which would reduce by half the fat load. We have looked at the feasibility of using the 2% solution in patients requiring sedation after elective cardiac surgery involving the use of cardiopulmonary bypass, comparing it with the 1% solution.

Methods

Forty patients undergoing myocardial revascularisation procedures gave written, informed consent to participate in the study that had been approved by the Hospital Ethics Committee and the Committee on Safety of Medicines. Patients were not studied if they had serious impairment of any organ system or of lipid metabolism, if they were more than 20% above their ideal body weight or if they had been receiving any medication with sedative properties. The anaesthetic technique was standardised: premedication consisted of droperidol, papaveretum and hyoscine; anaesthesia was induced with fentanyl 50 μg.kg^{-1} and thiopentone (up to 4 mg.kg^{-1}) and maintained with 66% nitrous oxide in oxygen; the trachea was intubated after pancuronium 0.15 mg.kg^{-1} had taken effect. Further doses of fentanyl and pancuronium were given as required. Hypertension was controlled with intravenous infusions of glyceryl trinitrate or sodium nitroprusside. At the end of the procedure artificial ventilation was continued and the patients transferred to the intensive care unit (ICU).

In the ICU the patients were allocated randomly to receive infusions of either 1% or 2% propofol for sedation. Analgesia was provided by bolus doses of papaveretum 2.5–5.0 mg as required.

Sedation was started as soon as the patients opened their eyes to command, at an initial rate of 50 mg.h^{-1} (5 ml.h^{-1} of 1% propofol or 2.5 ml.h^{-1} of 2% propofol). The rate of infusion was thereafter adjusted (up to a limit of 2 mg.kg^{-1}.h^{-1}) by the nursing staff, who attempted to maintain sedation at level 3 on the scale described by Ramsay and his colleagues [5] (drowsy and responsive to commands only). The propofol infusion was discontinued when the decision was made to stop artificial ventilation. As soon as the patient became alert and responsive, he/she was allowed to breathe spontaneously and their tracheas were extubated when spontaneous ventilation and arterial blood gases were satisfactory. Details of any drug or fluid therapy given during the period of sedation were recorded.

Monitoring

Sedation The level of sedation was assessed hourly according to the Ramsay scale and an estimate made of the proportion of time spent at level 3. The number of adjustments to the infusion rate was recorded. The overall

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Table 1. Demographic data, mean (SD).

	1% propofol	2% propofol	p
M/F	17/3	20/0	NS
Age; years	63.1 (5.61)	57.9 (6.42)	0.01
Weight; kg	76.8 (10.67)	78.2 (9.63)	NS

NS, not significant.

adequacy and ease of control of sedation were assessed by the nursing staff, as good, adequate or poor. Times from the end of sedation to awakening (as judged by the ability to raise an arm on command) and tracheal extubation were noted. The total doses of propofol and papaveretum used were recorded.

Cardiovascular Heart rate, central venous pressure and arterial blood pressure were continuously displayed, and recorded every 15 min for the first hour of sedation and then hourly.

Respiratory Arterial blood gases and pH were measured immediately before sedation, hourly for the first 6 h and then just before discontinuing the propofol. The inspired oxygen concentration and barometric pressure were noted and the alveolar–arterial oxygen tension difference (A–aDO_2) calculated at these times, assuming an R value of 0.8.

Biochemical Blood samples were taken immediately before, at the end of, and 24 h after sedation for the following: haemoglobin, packed cell volume, white cell and platelet counts, urea, creatinine, bilirubin, alkaline phosphatase, aspartate aminotransferase, triglycerides and cholesterol. If lipid levels were raised, they were measured daily until they returned to normal.

Any adverse events occurring during sedation or recovery were recorded.

Statistics Contingency tables relating to overall adequacy and ease of sedation were reduced to 2×2 tables, combining good and adequate assessments and were analysed by the Fisher's Exact Test. The effect on cardiovascular parameters was assessed by analysis of covariance, having allowed for baseline as covariate; 95% confidence limits were estimated for the difference between formulations. The Wilcoxon Rank Sum Test was applied to all other continuous data.

Results

Twenty patients were admitted to each group, but one who received 1% propofol inadvertently received lorazepam on the evening before and the morning of surgery. This was not discovered until after entry into the trial, and her results are therefore excluded from summaries of all efficacy comparisons, but are included in safety analysis. Demographic data of the patients are shown in Table 1; the patients in the 1% propofol group were significantly older than those in the 2% group (p = 0.01).

Table 3. Adequacy and ease of control of sedation.

	Good	Adequate	Poor
Overall adequacy			
1% propofol	9	10	0
2% propofol	9	10	1
Ease of control			
1% propofol	9	10	0
2% propofol	11	7	2

Table 4. Recovery times; min.

	1% propofol	2% propofol
End of sedation to awakening		
Mean	10.9	36.8
SD	11.1	94.4
Median	10	5
Quartiles	3–14	2–15
Range	0–40	0–410
End of sedation to tracheal extubation		
Mean	97.6	96.4
SD	126.6	121.5
Median	50	62
Quartiles	39–149	41–199
Range	6–539	10–525

There were no statistically significant differences between the two groups.

Table 2 shows the duration of sedation and the total amounts of propofol and papaveretum used. There were no significant differences between the groups. Similarly, there were no differences between the number of adjustments made to the infusion rate per hour, or in the percentage of time spent at sedation level 3 (Table 2). Inappropriate levels of sedation (levels 1 and 6) occurred for 22% of time in the 1% group and 21% in those who received 2% propofol.

The overall adequacy and ease of control of sedation were deemed to be good or adequate for most patients (Table 3), with no significant difference between the two formulations. Adequacy of sedation was judged to be poor in one patient in the 2% group because he spent 77% of the period in either level 1 or 6. Ease of control of sedation was assessed as being poor in two patients who received 2%

Table 2. Drug doses, adjustments per h and time spent at level 3 sedation. Values are presented as mean (SD).

	1% propofol	2%propofol	p
Duration of infusion; min	624 (226)	516 (242)	NS
Propofol			
Mean dose; mg	763 (556.7)	540 (415.7)	NS
Range	70–2315	92–1630	
Rate; $mg.kg^{-1}.h^{-1}$	0.95 (0.47)	0.76 (0.35)	
Papaveretum			
Mean dose; mg	11.2 (9.6)	9.0 (4.9)	NS
Range	0–30.0	0–20.0	
Adjustments per h	0.97 (0.46)	0.85 (0.41)	NS
Percentage time sedation level 3	57.3 (17.4)	56.1 (27.6)	NS

NS, not significant.

Table 5. Effect on heart rate; beats.min^{-1}.

	Time								
	Minutes				Hours				
	0	15	30	45	1–4	5–8	9–12	13–16	17–20
1% propofol									
Mean	93.8	92.9	89.0	90.8	86.7	83.4	84.0	78.6	75.0
SD	19.8	19.1	19.1	17.1	14.0	11.8	14.8	9.4	—
N	19	18	17	17	19	18	12	5	1
2% propofol									
Mean	91.0	92.9	93.9	96.4	96.2	97.6	88.1	84.9	80.0
SD	16.9	13.9	16.3	14.4	17.0	13.6	14.2	17.8	—
N	20	20	19	18	20	17	7	5	1
95% confidence limits									
Upper	—	7.0	14.6	15.5	18.7	22.7	17.0	30.1	—
Lower	—	−3.4	0.1	0.3	3.4	7.7	−7.9	−9.4	—
p value	—	0.517	0.046	0.042	0.006	0.001	0.451	0.256	—

propofol, because the nursing staff felt that they had required excessive adjustments to the infusion rate.

Recovery times are shown in Table 4 and are skewed by a small number of patients.

The longer time range for the return of consciousness in the 2% propofol group is influenced by one patient, who was so sedated from his anaesthetic that propofol was not required until 11 h after surgery to facilitate ventilation. On cessation of the propofol infusion, he took 410 min to awaken, and a further 115 min before his trachea could be extubated, but his subsequent progress was uneventful. One patient who received 1% propofol was awake within 5 min of stopping sedation, but because of respiratory problems, it was decided to continue ventilation (for a further 539 min). Thus, because of the distribution of the recovery times, it is more appropriate to compare the median times from the end of sedation to awakening and end of sedation to tracheal extubation, which were very acceptable. There were no statistically significant differences between the two groups in any of the recovery times.

Arterial and central venous pressures were similar in both groups, but throughout the study the mean heart rates were consistently and significantly higher in those who received 2% propofol (Table 5).

Cholesterol and triglyceride levels were similar for the two groups. No patient had a raised cholesterol at any time. One patient who received 1% propofol had a normal baseline triglyceride level, but levels were elevated until 48 h after the drug was stopped. One other patient in this group had elevated triglycerides which remained high throughout the study. Two patients given 2% propofol had raised triglycerides, which remained high in one patient, but returned to normal in the other 24 h after stopping propofol. Other biochemical and haematological values were similar for the two groups.

Derived (A-a)DO_2 gradients were similar for the two groups throughout the study; they decreased slightly during the period of propofol infusion.

There were no adverse events that could be attributed to propofol administration.

Discussion

The purpose of the present study was to assess the feasibility of using a 2% solution of propofol for sedating patients in an ICU. We therefore chose a relatively homogeneous group of patients who had undergone coronary artery bypass surgery and who required sedation for a relatively short period of time. These patients are routinely sedated with propofol during the period of mechanical ventilation and the nursing staff have extensive experience in the use of propofol for this purpose. The study was randomised, but since this was the first study with the 2% formulation it was decided that it should not be performed in a double-blind manner. In fact, this would not be easy to do because although the solutions are identical in every respect, the initial infusion rate of 2% propofol is of course half that of the 1% formulation. The main indication for the stronger solution would be in more severely ill patients requiring much longer periods of sedation and who would benefit from a reduction in fat load.

The only difference between the groups was the consistently higher heart rate in those who received 2% propofol. We are unable to explain this. There was no difference in analgesic consumption between the groups, or in blood loss. The drugs were infused into a central vein so no comment can be made concerning local sequelae or pain on injection. There was no difference in the dose of the two preparations and recovery times were very similar, with the expected interindividual variation.

Propofol 2% appears to be a safe and 'nurse-friendly' preparation, which should be fully investigated as an alternative to the 1% solution for use in the intensive care unit.

Acknowledgments

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Ketorolac for postoperative analgesia in elderly patients

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Summary

Ketorolac was compared with papaveretum followed by paracetamol plus dextropropoxyphene orally, for postoperative pain relief in elderly orthopaedic patients. Seventy-two patients over the age of 65 years were entered into a double-blind, randomised trial. Pain and pain relief were recorded during an intramuscular and an oral phase, lasting up to 8 days, and a global assessment was made at the end of the study. No difference was demonstrated between the two treatment groups. The incidence of side effects was similar in both groups. It was concluded that ketorolac could provide pain relief equivalent to papaveretum for many patients.

Key words

Pain; postoperative.
Analgesics; papaveretum, ketorolac, dextropropoxyphene.

Opioids remain the most commonly used drugs for the management of postoperative pain, despite their many side effects. The latter are a particular problem for elderly patients who can be particularly sensitive to the central depressant effects of these drugs. Ketorolac is a nonsteroidal anti-inflammatory drug which is devoid of central effects [1, 2]. Several studies have shown it to produce effective analgesia after major surgery, but the majority of the patients have been under 65 years of age [3–6].

The present study was designed to evaluate the efficacy and incidence of side effects of ketorolac during the first 8 days after orthopaedic surgery in elderly patients. To this end it was compared with papaveretum followed by Coproxamol (paracetamol with dextropropoxyphene).

Method

Seventy-two male and female patients over the age of 65 years, who were undergoing orthopaedic surgery, were studied. The trial was approved by the local Ethics Committees and informed written consent was obtained from each patient. Exclusion criteria included a history of gastric or duodenal ulcer within the previous year, known bleeding disorders, severe systemic illness, asthma, abnormal renal or hepatic function, addiction to alcohol or any other drug, allergy to aspirin-like drugs or papaveretum, and recent ingestion of any drugs, including analgesics, which were thought to affect the response to the study drugs.

The patients were premedicated 1 h before surgery with papaveretum and atropine and general anaesthesia was induced with a sleep dose of thiopentone and maintained with nitrous oxide and isoflurane or halothane in oxygen. Myoneural blocking drugs were used if necessary.

The study consisted of an intramuscular followed by an oral phase. Immediately after surgery, the patients were randomly allocated to one of two analgesic regimens, which were administered in a double-blind manner. One group was prescribed papaveretum 10 mg intramuscularly which could be repeated up to a maximum of 16 doses, i.e. 3 hourly for 48 h. Intramuscular analgesia was replaced by two oral Coproxamol tablets at the discretion of the nursing staff when they considered that potent analgesia was no longer necessary. The other group was given ketorolac 30 mg intramuscularly followed by 10 mg intramuscularly, again to a maximum of 16 doses. In these patients, the oral medication consisted of ketorolac 10 mg. In both groups, oral medication could be taken up to four doses per 24 h. Both injections were presented as a volume of 1 ml in brown coloured ampoules and the first dose was identified by a coloured label. During the oral phase, each patient was given two tubs of tablets. Tub A contained either two tablets of Coproxamol or two of placebo, while tub B contained one tablet of ketorolac or placebo. Instructions were to take two tablets from tub A and one from tub B. Medication was administered in this way to maintain the double-blind nature of the trial and to avoid altering the formulation of Coproxamol. Sufficient tablets were supplied for 5 days. If at any stage pain relief was found to be inadequate, the patient was removed from the trial and papaveretum was given as rescue medication.

Immediately before administration of the first dose, pain was assessed by the patient using a 100 mm visual analogue scale with 'no pain' (0 mm) and 'worst pain imaginable' (100 mm) at the extremes, and a verbal rating score (none = 0; mild = 1; moderate = 2; severe = 3). Pain (visual analogue score and verbal rating score) and pain relief by verbal rating score, (none = 0; slight = 1; moderate = 2; complete = 3) were recorded after 30 min, 60 min and then hourly for the first 6 h or until the second dose of analgesia was required. Arterial blood pressure, pulse rate, respiratory rate and side effects were also recorded throughout this period.

Patients were visited at the end of day 1, and then daily in the late afternoon throughout the oral and intramuscular phase until they had completed the trial. Pain was assessed as before. During the oral phase they were also questioned about sleep disturbances. The incidence of adverse effects

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Table 1. Patient and surgery data.

	Ketorolac $n = 36$	Papaveretum $n = 36$
Age; years, mean (SD)	75.4 (6.4)	74.8 (6.3)
Male: Female	7:28	7:29
Weight; kg, mean (SD)	65.4 (10.5)	65.7 (12.5)
Duration of surgery; h, median (range)	1.75 (1.0–4.0)	1.5 (0.5–3.0)
Site of operation		
Hip		
Total hip replacement	15	13
Hemi-arthroplasty	6	10
Screw/pin and plate	6	3
Ankle	4	1
Knee	4	6
Other	1	3

and concurrent medications were noted throughout the whole study period.

Statistical methods Results were analysed statistically using the two sample t-test for parametric and the Wilcoxon Rank Sum test for nonparametric data. Patients for whom a pain assessment was not recorded have had the missing assessment substituted by the larger of either the previous or the following assessment. Patients who withdrew before 3 h because they needed further analgesia had their last recorded assessment carried forward to 3 h. Summed Pain Intensity Differences (SPIDS) from baseline to 3 h were calculated for both the visual analogue scores (VAS) and verbal rating scores (VRS) using the trapezoidal method of area calculation [7]. Total Pain Relief (TOTPAR) was similarly calculated.

Results

Seventy-two patients entered the study, 36 in each group. Six patients required no intramuscular analgesia despite undergoing procedures which included hemi-arthroplasty and pin and plating, but did require oral medication. The detailed pain record of the immediate postoperative period for one patient was lost and one patient was unable to complete the visual analogue scale but could complete the verbal ratings. These were all in the ketorolac group. The sex of one patient who received papaveretum was not recorded. The groups were comparable with regard to sex, age, weight, duration and type of surgery (Table 1).

Pain measurements during intramuscular medication Baseline pain scores were similar in the two groups (Fig. 1).

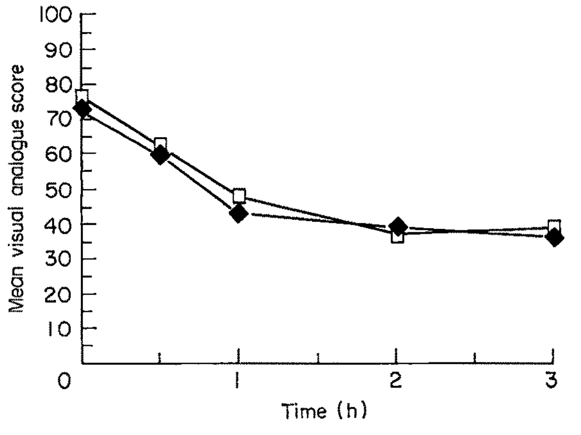

Fig. 1. Mean visual analogue scores during the first 3 h. □, ketarolac; ◆, papaveretum.

Table 2. Pain and pain relief during the immediate postoperative period.

	Ketorolac	Papaveretum	p
VAS–SPID			
Number of patients	28	36	
Mean	28.1	26.3	0.53
Range	−6.9 to 59.1	−4.0 to 57.1	
VRS-SPID			
Number of patients	29	36	
Mean	0.72	0.82	0.76
Range	−0.92 to 2.17	0.0 to 2.17	
TOTPAR			
Number of patients	29	36	
Mean	1.33	1.46	0.56
Range	0.0 to 2.58	0.0 to 2.54	

Significance of treatment difference p by Wilcoxon Rank Sum test. VAS, visual analogue score; SPID, summed pain intensity difference; VRS, verbal rating score; TOTPAR, total pain relief.

During the first 3 h, five of the patients who received ketorolac and three of those who received papaveretum had withdrawn because of inadequate analgesia. One patient who received papaveretum was withdrawn as a result of side effects. Only the results of the first 3 h were studied statistically since by 4 h, three of the remaining ketorolac group and eight of the papaveretum group had received a second dose of analgesia and so no longer completed detailed record cards. The numbers remaining were too small for accurate analysis. The median time interval to the second dose of medication was 6.1 h (range 3.0–26) for the ketorolac group and 5.6 h (range 3.0–60.0) for those receiving papaveretum.

The results of analysis of summed pain intensity differences (VAS and VRS) and pain relief (TOTPAR) from baseline to 3 h are shown in Table 2. Negative values for SPID indicate that the pain increased before the analgesia had any effect.

Global assessments were made by the patients at the end of day one, at 24 h and at 48 h after operation, using verbal rating scores for pain, and pain relief. The results of these are summarised in Table 3. p values are not given for 24 and 48 h because of the small numbers of patients who had not changed to oral medication or been withdrawn. The one patient who had severe pain and gained no pain relief from ketorolac had had a total knee replacement and was receiving continuous passive knee flexion, which may result in increased pain. Thirteen patients in total were removed from the trial before the oral phase because of inadequate

Table 3. Pain and pain relief scores during the intramuscular phase.

	Ketorolac	Papaveretum	
	Median (range)	Median (range)	p value
Day 1	$n = 30$	$n = 36$	
Pain	1 (0–3)	1 (0–3)	0.68
Pain relief	2 (0–3)	2 (1–3)	0.64
24 h	$n = 9$	$n = 12$	
Pain	1 (0–3)	1 (0–2)	
Pain relief	2 (0–3)	2 (1–3)	
48 h	$n = 2$	$n = 3$	
Pain	1 (0–1)	1 (1–2)	
Pain relief	2 (0–1)	3 (1–2)	

Pain; none = 0, mild = 1, moderate = 2, severe = 3.
Pain relief; none = 0, slight = 1, moderate = 2, complete = 3.

Table 4. Outcome and reasons for withdrawal.

(a) Intramuscular phase	Ketorolac	Papaveretum
No IM analgesia required	6	0
Inadequate analgesia	7	4
Adverse event	0	1
Other	0	1
(b) Oral phase	Ketorolac	Coproxamol
No oral medication required	1	2
Inadequate analgesia	2	3
Adverse event	3	2
Other	1	2
No more analgesia required	9	8
Completed 5 days study	13	13

analgesia, side effects, or 'other causes.' These are summarised in Table 4. A further three patients did not enter the oral phase since they required no analgesia after their intramuscular medication.

Pain measurements during oral medication A total of 56 patients entered the oral phase, 28 who received ketorolac and 28 who received Coproxamol, but only 25 in total (13 and 12) continued until the end of day five. The pain record card for one of the patients taking Coproxamol was missing. A summary of the reasons for withdrawal is shown in Table 4b; the most common reason for withdrawal from the study was that the patient no longer required analgesia. The results for pain and pain relief are summarised in Table 5. The only significant difference is seen in global pain on day two. Patients who received ketorolac had less pain than those who received Coproxamol, but by the following day there is no difference between the two groups.

Sleep disturbances Sleep disturbances were frequent. During the oral phase, 12/99 nights of patients taking ketorolac and 32/103 nights in the Coproxamol group were disturbed. Those patients who received ketorolac had more nights with sleep than those taking Coproxamol ($p < 0.01$ Chi-squared test). However, pain as the sole cause of disturbed sleep was not reported. The most frequent causes were noise (3/12 nights in the ketorolac group and 15/32 nights in the Coproxamol group), and 'inability to get comfortable'.

Adverse events The adverse events recorded during the study are shown in Table 6. The only severe adverse event was experienced by a patient in the papaveretum group, who complained of difficulty in breathing and the sensation of a swollen tongue. He was withdrawn from the trial, and recovered without further treatment. The incidence of nausea and vomiting appeared to be less in those patients taking ketorolac than in the group who received papaveretum intramuscularly, although the numbers were too small for statistical analysis.

Table 5. Pain and pain relief scores during oral phase.

	Ketorolac	Papaveretum	
	Median (range)	Median (range)	p value
Day 1	$n = 27$	$n = 26$	
Pain	1 (0–2)	1 (0–2)	0.18
Pain relief	2 (1–3)	2 (1–3)	0.69
Day 2	$n = 20$	$n = 22$	
Pain	1 (0–1)	1 (0–2)	0.02*
Pain relief	2 (1–3)	2 (2–3)	0.40
Day 3	$n = 20$	$n = 20$	
Pain	1 (0–1)	1 (0–2)	0.33
Pain relief	2 (2–3)	2 (0–3)	0.93

p by Wilcoxon Rank Sum test.
Pain; none = 0, mild = 1, moderate = 2, severe = 3.
Pain relief; none = 0, slight = 1, moderate = 2, complete = 3.

Table 6. Side effects.

(a) Intramuscular phase	Ketorolac	Papaveretum
Nausea and vomiting	5	11
Indigestion	0	0
Constipation	0	1
Somnolence	1	1
Confusion	0	0
Other	3	7
(b) Oral phase	Ketorolac	Coproxamol
Nausea and vomiting	3	1
Indigestion	1	3
Constipation	5	3
Somnolence	0	1
Confusion	2	1
Other	8	4

Overall assessment A global assessment was made for each patient by the observer at the end of the study. These are shown in Table 7. There was again no statistically significant difference between the two groups at this stage.

Discussion

This study has shown that ketorolac is an acceptable postoperative analgesic in some, but not all, elderly orthopaedic patients. It failed to show any difference between ketorolac 30 mg followed by ketorolac 10 mg and papaveretum 10 mg, or between ketorolac 10 mg orally and two Coproxamol 2 tablets. Other studies have shown that ketorolac 30 mg and 90 mg were similar to or better than morphine 12 mg for patients with moderate or severe pain after major or orthopaedic surgery [4, 5], although some studies would disagree [8]. It has frequently been reported that postoperative pain is poorly managed [9], and this has been supported by this study, in which 60% of those taking ketorolac and 56% of those taking papaveretum still had moderate or severe pain at the end of 1 h. However, this contrasts with the six patients who required no intramuscular analgesia at all until the following day, at which stage oral analgesia was adequate; i.e. there was a wide range of pain perception for similar operations. Even in those studies which show that ketorolac is inadequate for severe pain, a morphine-sparing effect, which may be of value, has been documented [10]. This would avoid the potential respiratory depression associated with increasing doses of opioids. Elderly patients have been shown to experience more pain relief from any stated dose of analgesia than younger patients [11], an observation which may support the results from this study.

Table 7. Global assessment at end of study.

	Ketorolac	Papaveretum
Very good	9	11
Good	15	8
Fair	2	11
Poor	8	5
Unable to comment	2	1

In this study a loading dose followed by a maintenance dose was used, because there is evidence of gastric irritation when the dose exceeds 120 mg/day [12]. Clinically, ketorolac 30 mg provides more effective analgesia of longer duration than ketorolac 10 mg, with median time to the next dose 6.0 h after 30 mg compared with 4.9 h after 10 mg. It was therefore decided that a loading dose of 30 mg initially would be given to establish reliably good analgesia, with top-up doses of 10 mg to maintain analgesia and provide greater flexibility, while decreasing the risk of side effects. The same dose could be continued into the oral phase as the bioavailability is approaching 100% [13]. The maximum dose taken by any patient in this study was 40 mg/day, orally.

Elderly patients are likely to have an altered ability to handle drugs as a result of the physiological changes of ageing, such as a reduction in cardiac output, decreased renal and hepatic blood flow, and altered drug binding. Ketorolac is highly bound to plasma proteins and is metabolised mainly by conjugation with glucuronic acid and excreted predominantly in the urine, therefore it could be expected to show altered pharmacokinetics in the elderly. Other studies have shown that there is no difference in absorption of ketorolac between elderly and younger patients, but the half-life is prolonged [14]. In our study, the onset of analgesia occurred within 1 h, as has been shown in younger patients [13]. The duration of action of the intramuscular dose was prolonged compared with a previous study which used the same dose regimen in younger patients undergoing gynaecological surgery [3] (6.1 h (range 3.0–26) compared with 4.67 hours (range 1.0–16.3)). Our results agree with those of other workers [14]. It is therefore necessary to consider these facts when ketorolac is prescribed in the elderly.

In conclusion, ketorolac is suitable for use as a postoperative analgesic in many elderly patients with moderate to severe pain, provided that the slightly prolonged duration of action is noted. It has no demonstrable advantage over papaveretum for analgesia, but may be useful when the respiratory effects of opioids are to be avoided, or in order to decrease the dose of opioids.

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The occurrence of bacteraemia associated with the use of oral and nasopharyngeal airways

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Summary

In order to determine whether placement of oral or nasopharyngeal airways during anaesthesia induces a significant bacteraemia, 36 ASA grade 1 or 2 patients undergoing body surface surgery, in whom it was anticipated that spontaneous respiration would be maintained, were randomly allocated to one of two groups. One group was given oral airways and the other, nasopharyngeal. A series of blood samples, which were taken before and after airway insertion, were cultured aerobically and anaerobically. Nasal and oral swabs were taken at the same time. Single isolates of Corynebacterium species and Acinetobacter species, together with two isolates of Staphylococcus epidermidis were grown from one culture bottle from 4 of the 36 patients studied. None of the oral or nasal swabs, or any of the subsequent or previous blood samples produced positive cultures for these organisms in these four patients. We believe that these results represent skin commensal contamination rather than bacteraemia in these four patients, and that bacteriological considerations should not influence decisions about the type of airway used during anaesthesia. However, prophylactic antibiotic therapy should still be provided for all high risk cases.

Key words

Equipment; airway.
Complications; bacteraemia.

The insertion of an oral or nasopharyngeal airway, to assist in the management of the unconscious or heavily sedated patient, is a well recognised procedure which is frequently undertaken by a wide variety of medical practitioners. Previous work has demonstrated the occurrence of bacteraemia when instrumentation of the upper airway is performed for a number of purposes [1–3]. The aim of this study was to assess the risk of bacteraemia resulting from the introduction of either an oral or a nasopharyngeal airway during the conduct of general anaesthesia.

Methods

Clinical study method The study was approved by the hospital ethics committee and written informed consent was obtained from each participant. Patients undergoing anaesthesia for body surface surgery, who were spontaneously breathing without a tracheal tube, were considered suitable for study. Patients were not studied if they had major systemic disease (ASA 3–5), valvular heart disease, pre-existing pharyngeal pathology, current infection, evidence of immuno-compromise, or administration of antibiotics within the 72 h period before surgery.

Participants in the study were randomly allocated to one of two groups. In group 1, a nasopharyngeal airway was inserted to assist with conduct of anaesthesia while in group 2, an oral airway was used. Both types of airway were disposable, made of plastic and were removed from their sterile packaging just before usage and lubricated with sterile lubricating jelly.

On arrival in the anaesthetic room, an intraveneous cannula was placed in one or other of the patient's cubital fossae using full aseptic technique. Ten ml of blood was then drawn through this cannula and 5 ml was placed in each of two blood culture bottles. Intravenous induction of anaesthesia was then performed using the same cannula.

After induction of anaesthesia, the patient was allowed to breathe nitrous oxide, oxygen and a volatile agent administered through a facemask alone. Once a satisfactory level of anaesthesia had been reached, microbiological swabs were taken. One swab was taken from the nose and another from the mouth. Oral hygiene was also assessed and was graded as 'good' if the mouth was clean and there was little or no dental plaque and 'poor' if dental plaque was evident, on gross examination.

The airway (either nasopharyngeal or oral) was then inserted. Two minutes after insertion, a further set of blood cultures was taken from the cubital fossa opposite to the one which had been used previously. Ten minutes after placement of the airway, another set of cultures was taken in a similar manner.

The surgical procedure was then performed. At the end of surgery the pharynx was assessed for the presence of blood and the patients were divided into three groups according to the degree of trauma induced by airway placement. Trauma was assessed as: no trauma, easy passage of airway and no blood in pharynx at end of operation; mild trauma, easy passage of airway or slight difficulty in insertion, but some blood present in pharynx at end of operation; moderate trauma, difficulty in insertion of airway and significant bleeding present in pharynx at end of operation.

Microbiological laboratory method Ten ml of blood was drawn from each venepuncture. Five ml was placed in each of two 'Bactec' culture bottles, which were then incubated for up to 3 weeks. One bottle was suitable for aerobic culture and the other for anaerobic. An automated carbon dioxide detector was used to detect positive results. Positive

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Table 1. Oral hygiene. Condition of the mouth and oropharynx. *n* = number of patients.

	Group 1 Nasopharyngeal airway		Group 2 Oral airway	
Condition	*n*	%	*n*	%
Good	16	89	17	94
Poor	2	11	1	6

cultures were plated out onto chocolate, blood and MacConkey agar.

The microbiological swabs were transported in 'Amies' transport media. All swabs were plated onto growth media, but only in the event of a positive blood culture were the resulting colonies identified. Throat swabs were plated onto blood agar, a streptococcus selective agar and a tellerite plate. Nasal swabs were plated onto blood agar only.

Results

Demographic data Eighteen male and 18 female patients were admitted to the trial. The mean age was 42.2 years (range 20 to 73 years). All patients fulfilled the criteria outlined above.

Oral hygiene The results of the assessment of the patients' oral hygiene is presented in Table 1.

Airway trauma Two patients in the nasopharyngeal airway group had mild trauma to the airway. All other patients had no trauma.

Microbiological survey In the group 1 nasopharyngeal airway patients, a single isolate of *Corynebacterium* species was grown from the blood of one patient. This blood was taken 2 min after airway introduction and growth occurred in only one of the two culture bottles 7 days after incubation. Nasal and throat swabs taken from this patient failed to grow *Corynebacterium* species as did the 10 min post-insertion blood culture. Oral hygiene in this patient was reported as good and no airway trauma had been induced.

One other patient in this group had a positive blood culture result. In this patient, *Staphylococcus epidermidis* was detected after 7 days' incubation of blood taken 2 min after the airway was inserted, but growth occurred in only one culture bottle. This patient was also described as having good oral hygiene and the micro-organism was not grown from either swab or from the blood cultures taken 10 min after insertion of the airway. Airway trauma was not induced in this patient.

In the group 2 oral airway patients a single isolate of *Acinetobacter species* was detected 18 h after incubation of blood taken before introduction of the airway in one patient in this group. This patient was reported as having good oral hygiene and airway trauma did not occur. *Acinetobacter* was not grown from the nose or throat swab, or from post insertion blood cultures. Blood from another patient grew *Staphylococcus epidermidis* after 48 h from blood taken 10 min after placement of the airway. Growth occurred in both culture bottles. This patient also had good oral hygiene and did not experience airway trauma. However, *Staphylococcus epidermidis* was not grown from either the nose or throat swabs or the two postinsertion blood cultures.

Discussion

Bacteraemia is a potentially serious clinical occurrence which may result in bacterial endocarditis. Patients with prosthetic heart valves, rheumatic valvular disease, suppressed immunity or those undergoing prosthetic joint replacement are particularly at risk. It is therefore important that procedures involving upper airway instrumentation be considered in terms of their potential to cause such a bacteraemia, particularly in these groups of patients. The use of either oral or nasopharyngeal airways is a well accepted practice in the management of patients under general anaesthesia and elsewhere. Nasopharyngeal airways may have particular advantages over oral airways in some circumstances. especially when there is a risk of damage to teeth because of poor dentition or reconstructive dental surgery. Our study has assessed the risk of bacteraemia during the use of either oral or nasopharyngeal airways.

Previous workers have studied the occurrence of bacteraemia following a variety of procedures. The results have been very variable, presumably because of differences in the procedures studied and the techniques used to detect the bacteraemia. Dinner *et al.* demonstrated a significant bacteraemia in three out of 54 patients undergoing nasotracheal intubation. The incidence did not appear to be influenced by the use of a topical vasoconstrictor or by the occurrence of trauma during intubation [1]. Gerber *et al.* found no incidence of bacteraemia in 18 patients undergoing nasotracheal intubation and in only one out of 32 patients undergoing oral intubation [2]. Patients undergoing orotracheal intubation and oesophageal balloon dilatation have been studied by Hansen *et al.* who demonstrated a bacteraemia in 12 out of 19 patients. The source of the bacteraemia was concluded to be the patients' oropharyngeal flora [3]. Cannon *et al.* studied a nonrandomised group of patients undergoing emergency intubation by both the nasopharyngeal and the oral route. Four out of 14 patients intubated nasally developed a bacteraemia. Seven patients were intubated orally, One of these was excluded because of positive pre-intubation cultures. None of the others developed a bacteraemia. They concluded there was a substantial risk of bacteraemia associated with emergency nasopharyngeal intubation [4].

In our study, blood cultures were positive in only four patients. All the micro-organisms isolated are well known skin commensals. While some are also present in the upper respiratory tract, we consider that their growth was almost certainly the result of contamination from the patients' skin. *Staphylococcus epidermidis* was grown from the blood of two patients. The organism was grown from only one set of cultures in each case and it was not isolated from nasal or oral swabs taken from either patient. Similarly, the *Coryriebacterium* species was found in only one set of cultures and was not grown from the oral or nasal swabs. The *Acetinobacter* species was grown from the blood sample taken before airway introduction thereby excluding the possibility that it represented a significant bacteraemia. Although no significant bacteraemia was detected in this group of patients after airway insertion, we would still recommend prophylactic antibiotic therapy in high risk patients.

Our study has not demonstrated a significant incidence of bacteraemia associated with the insertion of either oral or nasopharyngeal airways during general anaesthesia. On the basis of these findings, the decision as to whether or not to use an airway, and which type would be most appropriate, could be made on other clinical grounds alone.

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A comparison of two approaches to sciatic nerve block

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Summary

This study compared the posterior and popliteal fossa approaches for sciatic nerve block. Patients scheduled to undergo foot surgery were allocated randomly into one of two groups: group A ($n = 20$) received sciatic nerve block via the posterior approach and group B ($n = 20$) received a block using the popliteal fossa approach. All blocks were performed with the aid of a peripheral nerve stimulator and alkalinised 0.5% bupivacaine with 1 in 200 000 adrenaline was injected in a dose of 2 mg.kg^{-1}. Nineteen of 20 blocks in group A were successful compared with nine of 20 in group B ($p < 0.01$). There was no significant difference between the groups in respect of time to onset or duration of block. Patients in group B reported less discomfort during performance of the sciatic nerve block but required supplementary nerve blocks more frequently. We recommend the use of the posterior approach for sciatic nerve block.

Key words

Anaesthetic techniques, regional; sciatic nerve block.

Sciatic nerve block is a well recognised technique for providing anaesthesia and analgesia of the lower limb. Several approaches to the nerve may be used including the anterior [1] and lateral [2] approaches (which have the advantage of easy patient positioning but may be technically difficult for anatomical reasons) and the posterior [3] and popliteal fossa [4] approaches. A possible advantage of the popliteal fossa approach over higher approaches is the avoidance of paralysis of the hamstring muscles; this may allow better mobility in the postoperative period.

The aim of our study was to compare the posterior and popliteal fossa approaches with respect to success rates, onset times, duration of blocks and discomfort to patients during insertion.

Methods

Forty healthy adults admitted for elective unilateral foot surgery were allocated randomly to receive a sciatic nerve block by either the posterior approach (group A, $n = 20$) or the popliteal fossa approach (group B, $n = 20$). Patients were not studied if there was a history of allergy to local anaesthetics, or any neurological or neuromuscular disease including low back pain or sciatica. The study was approved by the local Research and Ethics Committee, and patients gave informed consent before participating.

All patients were premedicated with oral temazepam 10 to 30 mg between 1 and 2 h pre-operatively, and venous access was secured on arrival in the anaesthetic room. Posterior approach sciatic nerve block was performed with the patient in the semiprone position. The injection was made from a point 3–4 cm perpendicularly below the midpoint of a line between the greater trochanter and the posterior superior iliac spine. Popliteal fossa approach sciatic nerve block was performed with the patient in the prone position. The injection was made from a point 7 cm cephalad and 1 cm lateral to the midpoint of the popliteal fossa skin crease. Nerve block was performed using a Stimuplex peripheral nerve stimulator (B. Braun Medical, Aylesbury, Buckinghamshire) and a short-bevelled, insulated needle (100 mm, 21 gauge). The needle was positioned to obtain movement of the foot, ideally plantar flexion, with a current of 0.5 mA at 2 Hz. After careful aspiration, correct needle positioning was confirmed by the abolition of muscle twitches following a 2 ml test dose of local anaesthetic. The remainder of the total calculated dose was then injected over 2 min. A dose of 2 mg.kg^{-1} bupivacaine 0.5% with adrenaline 1:200000, alkalinised with 0.1 mmol sodium bicarbonate per 10 ml solution immediately before injection [5], was used for all blocks.

Blocks were performed by one investigator (A.W.A.K.) who had acquired comparable experience with each approach, and assessed by either of two investigators (D.M.C., J.G.T.) unaware of the approach used. Times to analgesia and anaesthesia were assessed at 5-min intervals for up to 45 min with a short-bevelled 27 gauge needle, and

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Table 1. Patient data, presented as mean (SD).

	Group A (posterior) (n = 20)	Group B (pop. fossa) (n = 20)
Female : male	18 : 2	16 : 4
Age; years	52 (13)	54 (12)
Weight; kg	62 (8)	66 (7)

Table 2. Outcome of blocks.

	Group A (posterior) (n = 20)	Group B (pop. fossa) (n = 20)
Successful*	19	9
Supplemented†	1	6
Failed	0	5

* $p < 0.01$.
† All supplemented blocks were then successful.

the distribution of the block was noted. Complete or partial motor block was assessed by the ability of the patient to move his or her toes. Supplementary ankle blocks were performed using 0.5% plain bupivacaine if the sensory block was considered to be inadequate. If the territory of the saphenous nerve extended into the surgical field it was blocked at the knee.

Intravenous sedation with midazolam was available if requested by the patient. General anaesthesia was administered to patients in whom nerve block was inadequate for surgery. A below-knee tourniquet was used in all patients.

The time to first systemic analgesic requirement was used as an indicator of the duration of useful postoperative analgesia. Patients were prescribed morphine 10 mg intramuscularly or Coproxamol (dextropropoxyphene 65 mg and paracetamol 650 mg) two tablets, 4-hourly on demand.

Patients were asked to grade the discomfort associated with insertion of the nerve block as painless, slightly uncomfortable, very uncomfortable or painful. Patients were also asked if they would accept the same form of anaesthesia again.

Statistical analyses were performed using Chi-squared and Mann–Whitney U tests. A probability value of less than 0.05 was considered to be statistically significant.

Results

Groups were well matched in respect of age, weight, sex distribution and type of operation (Table 1). The commonest surgical procedure was first metatarsal osteotomy with either fusion or silastic implantation.

The outcome of the blocks is summarised in Table 2. In group A (posterior approach) 19 blocks were adequate for surgery without supplementation compared with nine in group B (popliteal fossa approach) ($p < 0.01$). One block in group A was supplemented with a tibial nerve block at the ankle. Six blocks were supplemented in group B, five with tibial nerve blocks and one with a deep peroneal nerve block. All supplemented blocks were adequate for surgery. Thus there were no failed blocks in group A but five blocks in group B were inadequate for surgery. In two of these patients, no block was demonstrable 45 min after injection of local anaesthetic; in another two, the common peroneal nerve was not blocked. These four patients received general anaesthesia before surgery. One patient experienced pain during surgery despite an apparently adequate block and required general anaesthesia for completion of surgery. In two patients in each group the territory of the saphenous nerve extended into the operative field, and saphenous nerve block at the knee was required before surgery.

Time to onset of analgesia to pinprick was similar in the two groups. The mean times to complete loss of sensation and motor block were also similar but these both occurred significantly more frequently in group A than group B ($p < 0.02$) (Table 3).

The duration of postoperative analgesia (Table 4) was not significantly different between groups. Two patients in group A and one patient with a successful block in group B required opioid analgesia after block regression. All five patients with failed block in group B required opioid analgesia in the postoperative period.

Table 5 summarises discomfort during insertion of the sciatic block. Most patients in group A found the procedure slightly uncomfortable, and three found it very uncomfortable. All patients in group B found block insertion painless or slightly uncomfortable.

Similar numbers of patients in each group requested intravenous sedation (four of 20 in group A and two of 15 in group B). All patients in whom nerve block was successful would be happy to have the same form of anaesthesia again. No patient experienced paraesthesiae in the postoperative period.

Discussion

The popliteal fossa approach was examined by Rorie *et al.* [6] in 130 patients who underwent a variety of surgical procedures on the foot. Nerve blocks were performed by eliciting paraesthesiae. Satisfactory anaesthesia for surgery was achieved in 82.3% of patients; 11.5% required intravenous sedation and/or further local anaesthesia, and 6.2% received general anaesthesia during surgery. However, 3.4% of patients experienced postoperative paraesthesiae. These authors concluded that the popliteal fossa approach provides satisfactory anaesthesia with a low incidence of complications.

We used a peripheral nerve stimulator to aid nerve localisation, and short-bevelled insulated needles which have been reported to reduce the risk of neuronal damage [7–10]. The approach used was that described by Macrae [4], 7 cm above the popliteal fossa skin crease. Alkalinisation of bupivacaine has been shown to reduce the latency and increase the duration of sciatic nerve block [5]. Location of the sciatic nerve was more difficult using the popliteal fossa approach than the posterior approach, and once the nerve had been located, a small

Table 3. Time to onset of nerve block, presented as mean (range).

	Group A (posterior) (n = 20)	Group B (pop. fossa) (n = 15)	p
Analgesia to pinprick; min	8.8 (5–20)	9.3 (5–20)	NS
Loss of sensation; min*	19.4 (5–35)	20.0 (5–35)	NS
Motor block; min†	21.3	23.1	NS

* Complete loss of sensation occurred in 16 patients in group A and 6 in group B, $p < 0.02$.
† Motor block occurred in 16 patients in group A and 6 in group B, $p < 0.02$.

Table 4. Duration (h) of useful analgesia.

	Group A (posterior) (n = 20)	Group B (pop. fossa) (n = 15)	p
First analgesia required; mean (range)	18.7 (7–34.5)	19.2 (9–36)	NS
Complete analgesia at 15 h; number	16	9	NS

Table 5. Number of patients who experienced discomfort during insertion of block.

	Group A (posterior) (n = 20)	Group B (pop. fossa) (n = 20)
Painless	0	8
Slightly uncomfortable	17	12
Very uncomfortable	3	0
Painful	0	0

change in needle position resulted in a loss of ankle movement.

We found that the popliteal fossa approach produced fewer successful blocks than the posterior approach. In 40% of patients only one division of the sciatic nerve was blocked from the popliteal fossa. Anatomical texts describe the sciatic nerve dividing into its common peroneal and tibial components within the popliteal fossa [11] and while individual variation is acknowledged, its extent is poorly defined. A 10% incidence of division in the greater sciatic foramen is quoted by some texts [12,13]. Others describe the division at a variable distance above the popliteal fossa [14]. The high incidence of one-component blocks surprised us and suggests that higher division may occur more frequently than was suspected previously. It may be that a slightly higher approach to the nerve in the posterior thigh would produce a complete block more frequently.

The popliteal fossa approach caused less discomfort than the posterior approach, possibly because the nerve is more superficial and requires less muscle transfixion in the former location. However, more patients required supplementary nerve blocks after the popliteal fossa approach had been used, and this caused additional discomfort.

Below-knee tourniquets are not used widely in the UK. Their use enabled surgery to be performed on patients with adequate sciatic block without the need for general anaesthesia or additional local anaesthesia of the femoral nerve or lumbar plexus. Good surgical conditions were produced despite the theoretical difficulty of compressing all blood vessels in the presence of two bones. It is essential to position the tourniquet a hand's breadth below the tibial tuberosity to avoid compression damage to the common peroneal nerve. Two patients described discomfort from the tourniquet; most of the remainder were aware of its presence but did not find it distressing. Saphenous nerve block at the knee might have prevented awareness of the tourniquet but this was performed in only two patients in each group, in whom the territory of the saphenous nerve extended into the surgical field.

In conclusion, we found the popliteal fossa approach to sciatic nerve block with the technique described to be less reliable than the posterior approach because of greater difficulty of nerve location and a high incidence of partial failure. We recommend the posterior approach to the sciatic nerve for anaesthesia of the foot.

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Oxygen saturation and cardiovascular changes during fibreoptic intubation under general anaesthesia

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Summary

Sixty patients who required fibreoptic nasotracheal intubation were studied. Arterial oxygen saturation, arterial blood pressure and heart rate were monitored continuously during fibreoptic intubation under deep halothane anaesthesia. There were significant decreases ($p < 0.001$) in arterial blood pressure and heart rate despite administration of intravenous colloid and atropine. Almost one third of the patients (18 out of 60) suffered a decrease in arterial oxygen saturation below 90% during the intubation sequence and in five patients the saturation fell below 80%. The episodes of desaturation were not related to the induction–intubation time or to the grade of laryngeal visibility at direct laryngoscopy.

Key words

Intubation, tracheal; fibreoptic, difficult.

The first report of the use of a flexible fibreoptic device as an aid to intubation of the trachea was by Murphy [1]. Flexible fibreoptic intubation of the trachea is now the method of choice when direct laryngoscopy is expected to be difficult. Awake fibreoptic intubation under topical anaesthesia is logical in such circumstances but most trainees are reluctant to attempt it until they have gained expertise in unconscious patients. We have used a method of fibreoptic intubation under general anaesthesia in which the patient breathes spontaneously throughout, both for training and in patients in whom awake intubation is unsuitable. This study investigates the arterial oxygen saturation ($Sp\text{o}_2$) and cardiovascular changes during fibreoptic intubation under general anaesthesia using a technique of spontaneous ventilation.

Methods

Sixty patients who required fibreoptic intubation before surgery for cervical spine disease were investigated in this study which had been approved by the local ethics committee. Patients in whom tracheal intubation by conventional methods was predicted to be difficult were included in the study. Criteria for inclusion were the presence of one of the following: Patil distance [2] < 5 cm; Mallampati score [3] III; restricted or absent movement of the atlanto-occipital joint; evidence of temporomandibular joint dysfunction. Patients were not studied if it was anticipated that control of the airway would be difficult; these patients underwent awake fibreoptic intubation.

Premedication with intramuscular papaveretum and hyoscine and with xylometazoline nose drops was administered 90 min before induction of anaesthesia.

On arrival in the anaesthetic room continuous electrocardiograph and $Sp\text{o}_2$ monitoring were initiated. A 16-gauge intravenous cannula and a 20-gauge arterial cannula were then inserted after infiltration with lignocaine 1%. Some patients received a small dose of midazolam (1–3 mg) during this procedure. The arterial blood pressure was monitored continuously via the arterial cannula and a pressure transducer. A hard copy of the arterial blood pressure, heart rate and $Sp\text{o}_2$ measurements was made using a pen and chart recorder. Events during the intubation sequence were noted if they resulted in oxygen desaturation ($Sp\text{o}_2 < 90\%$).

The lungs were not pre-oxygenated. Anaesthesia was induced with a sleep dose of propofol and maintained using halothane in nitrous oxide 50% in oxygen via a facemask. The inspired halothane concentration was increased until anaesthesia was deep enough to allow the insertion of a Mathias oral airway. The chimney of the airway was connected to a Bain breathing system. 'Sleek' adhesive strapping was applied around the airway and over the mouth and one nostril. The jaw was held forward and the nostrils closed by an assistant so that a clear airway was maintained. Spontaneous ventilation was maintained throughout. Anaesthesia was deepened by increasing the halothane concentration until conditions suitable for endoscopy were achieved.

Haemaccel 500 ml was administered if the systolic arterial pressure decreased by 30% from the pre-anaesthesia value and atropine 0.6 mg was administered intravenously if the heart rate decreased below 50 beat.min^{-1}.

All intubations were performed by senior registrars under the supervision of a consultant. An Olympus LF1 fibrescope (Keymed Ltd) was loaded with a 6.0–7.0 mm flexometallic nasotracheal tube (Mallinkrodt) before intubation. The fibrescope was then inserted via the nasal passage and when the glottis had been visualised it was sprayed with 2–4 ml of lignocaine 4% through the fibrescope. The fibrescope was advanced into the trachea when the true and false cords had relaxed and a further 2 ml of lignocaine 4% was injected. The tracheal tube was railroaded over the fibrescope into the trachea after 30 s and its position in relation to the carina was checked before removal of the intubating laryngoscope. The time from

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Table 1. The diagnostic categories of patients in the study.

Diagnosis	Number of patients (n = 60)	%
Rheumatoid arthritis	19	31.7
Cervical spondylosis	13	21.6
Congenital malformation	10	16.7
Cervical disc protrusion	6	10.0
Osteoarthritis	4	6.7
Tumour	3	5.0
Trauma	3	5.0
Ossified posterior longitudinal ligament	2	3.3

Table 2. Findings at direct laryngoscopy.

Grade*	Number of patients (n = 60)	%
I	34	56.7
II	19	31.6
III	6	10.0
IV	1	1.7

* Classification of Cormack and Lehane [4].

induction of anaesthesia to successful intubation was recorded. The tracheal tube was then connected to the breathing system and the inspired halothane concentration reduced to the level required to maintain anaesthesia. Direct laryngoscopy was performed to grade the view of the glottis as described by Cormack and Lehane [4].

Statistical analysis of the cardiovasular and Spo_2 data was performed using Student's t-test for paired data.

Results

The mean age of the patients was 53.6 years (range 16–88). There were 37 females and 23 males in the study. The indications for surgery are summarised in Table 1 and the findings at direct laryngoscopy in Table 2.

The mean time from induction to intubation was 13.2 min (range 5.0 to 28.0 min). There was no relationship between the time to intubation and the findings at direct laryngoscopy or episodes of oxygen desaturation (see below).

Table 3. Cardiovascular changes during fibreoptic nasotracheal intubation in anaesthetised patients. Significant differences from baseline values are denoted by * ($p < 0.001$) (paired t-test). All values are mean (SEM) and (range).

(n = 60)	Baseline	Lowest
Systolic arterial pressure; mmHg	140.7 (3.0) (103–200)	94.0 (2.0)* (50–122)
Heart rate; beat.min^{-1}	84.0 (2.5) (48–132)	73.0 (2.2)* (44–111)

There was a significant decrease in systolic arterial pressure ($p < 0.001$) during the intubation sequence despite efforts to restore pre-anaesthesia values with infusion of colloid (Table 3). There was also a significant decrease in heart rate which would have been more profound had atropine not been used in 40% of the patients. There was no pressor response or heart rate increase during intubation in any patient.

Eighteen patients (30%) developed Spo_2 less than 90% during the procedure and in five (8.3%) it was less than 80%. The occurrence of desaturation was not predicted by the findings at direct laryngoscopy (Table 4). Seventeen of these 18 patients were Cormack and Lehane grade I or II. One patient with a grade III laryngoscopy became desaturated to 88% secondary to brochospasm after successful intubation of the trachea. Five of the six grade III patients, and the only patient with a grade IV laryngoscopy, maintained Spo_2 above 90% throughout the procedure. Desaturation was not related to the induction–intubation time.

The timing of the episodes of desaturation in relation to manoeuvres in the intubation sequence as well as the lowest saturation recorded are shown in Table 4. The majority of episodes of desaturation (8 of 18) occurred after insertion of the airway or because of coughing and subsequent loss of control of the airway after injection of lignocaine. It was necessary to paralyse one patient with suxamethonium to regain control of the airway. Five patients had mild desaturation following induction of anaesthesia and a further three developed Spo_2 < 90% associated with

Table 4. The lowest oxygen saturation (Spo_2), the reason for desaturation, the timing of desaturation and glottic visibility at direct laryngoscopy (graded according to Cormack and Lehane [4]) in the 18 patients who developed Spo_2 < 90% during the intubation sequence.

Lowest Spo_2	Reason for desaturation	Timing of desaturation	Grade
89%	hypoventilation	after induction	II
89%	obstruction	airway insertion	I
18%	coughing	airway insertion	II
85%	hypoventilation	after induction	II
89%	hypoventilation	after induction	I
89%	cardiac depression	bradycardia	I
76%	coughing	lignocaine to cords	I
88%	coughing	lignocaine to cords	I
81%	hypoventilation	after induction	I
77%	coughing	lignocaine to cords	I
88%	shunting	tracheal tube in right main bronchus	I
88%	cardiac depression	bradycardia	II
89%	coughing	lignocaine to cords	I
74%	airway obstruction	airway insertion	I
47%	coughing	lignocaine to cords	I
89%	cardiac depression	bradycardia	I
89%	hypoventilation	after induction	I
88%	bronchospasm	after intubation	III

bradycardia. The episodes of desaturation in the remaining two patients were unconnected with the intubation technique; one was associated with intubation of the right main bronchus and the other with mild bronchospasm after successful intubation of the trachea. Many patients had episodes of coughing which did not result in desaturation. Fourteen patients received midazolam, but this did not influence the incidence of desaturation.

Discussion

The popularity of fibreoptic intubation has increased since the introduction of dedicated flexible fibreoptic laryngoscopes. However, it remains a skill possessed by a minority of anaesthetists in this country, the principal obstacles to dissemination of competence being the relatively fragile nature of a costly instrument and the difficulties of training. The fact that awake intubation is (relatively) easy with the fibrescope is a great contribution to patient safety.

Fibreoptic intubation under general anaesthesia does have some advantages. The patient is not conscious of discomfort and the passage of time, so that neither patient nor operator is embarrassed by incompetence. The incidence of coughing is reduced. Nevertheless there are major disadvantages to using general anaesthesia. The patient is no longer able to maintain his own airway, and therefore desaturation can occur. The soft palate, tongue and epiglottis tend to fall against the posterior pharyngeal wall [5] and can be difficult to dislodge so that even if the airway is clear enough for spontaneous or controlled ventilation to occur it may be difficult for the operator to obtain a view of the laryngeal inlet. An assistant capable of maintaining not only a clear airway but one clear enough for fibreoptic laryngoscopy is required. The assistant must have considerable stamina.

Fibreoptic intubation under general anaesthesia can be performed while the patient is apnoeic after neuromuscular paralysis. Finfer *et al.* [6] and Marian *et al.* [7] reported $S\text{po}_2$ changes during apnoeic fibreoptic intubation. The lungs were pre-oxygenated for 3 min in both studies and all patients had normal anatomy. In the study by Finfer *et al.* [6], intubation was achieved within 1 min and $S\text{po}_2$ did not decrease below 98%. Marian *et al.* [7] took up to 3 min to intubate and found that $S\text{po}_2$ declined steeply after 1 min so that 73% of their patients desaturated below 90%, and 20% below 80%; the authors concluded that ventilation should be continued, whether spontaneous or controlled, during fibreoptic intubation. Our results show that we were unable to prevent desaturation by allowing spontaneous ventilation with an $F\text{io}_2$ of 0.5. A higher inspired oxygen concentration might have prevented some of the episodes of desaturation but we have found that it can be difficult to achieve an adequate depth of anaesthesia, even with 5% halothane, due to leaks in the system. Inadequate depth of anaesthesia resulted in coughing and desaturation in seven (12%) of our patients. In other patients, the desaturation we encountered was generally transient and broadly similar to the degrees reported recently [8] as being the temporary consequence of thiopentone induction and spontaneous ventilation.

The cardiovascular changes during fibreoptic intubation after intravenous induction and neuromuscular blockade are similar to those seen during direct laryngoscopy [6,9,11]. However, our technique produced marked hypotension and bradycardia, which could not be prevented completely by intravenous fluids and atropine. The cardiovascular depression might be less severe with another volatile agent but control of the airway is probably easiest with halothane.

The technique we have used is not ideal. In addition to the desaturation and cardiovascular depression already mentioned, we have found that it is difficult to prevent pollution of the anaesthetic room due to leaks. It should be noted that none of our patients had normal anatomy and some were very difficult, with disease of the temporomandibular joint or craniocervical junction.

We prefer to perform fibreoptic intubation under topical anaesthesia and minimal or no sedation. The cardiovascular stability associated with this technique is striking [12] and although desaturation can occur it is easily reversed. Dykes and Ovassapian [13] have recommended that trainees learn the technique on awake patients (after considerable practice on mannequins) before attempting it under general anaesthesia. It will be interesting to see whether this becomes the norm in the UK.

Some patients, such as the very young and the very nervous, are unsuitable for an awake procedure. An apnoeic general anaesthetic technique has restricted application because rapid intubation is required and this may not be possible if the patient has abnormal anatomy or if the operator is inexperienced. Spontaneous ventilation under general anaesthesia allows prolonged endoscopy but is associated with cardiovascular depression and desaturation. The most severe episode of desaturation (to 18%) in our study occurred during coughing and laryngospasm after insertion of a Mathias airway into a 20-year-old patient with osteogenesis imperfecta. Suxamethonium was given and the procedure continued with controlled ventilation. If general anaesthesia must be used, a technique involving neuromuscular blockade and controlled ventilation for part or all of the procedure, such as that described by Coe *et al.* [14], may be better than that described in this paper.

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Electronic and disposable patient-controlled analgesia systems

A comparison of the Graseby and Baxter systems after major gynaecological surgery

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Summary

We have compared the performance of the Baxter disposable with the Graseby electronic patient-controlled analgesia system in 30 patients following major gynaecological surgery. Patients were allocated randomly to receive analgesia via the Baxter or Graseby device for postoperative pain relief. There were no significant differences between the two groups with regard to postoperative pain relief or sedation as measured by visual analogue scale. Requirements for antiemetic drugs and patient acceptability were similar. Mean (SEM) morphine demanded over 30 h was 35.7 (6.6) in the Graseby group and 35.1 (8.5) in the Baxter group.

Key words

Analgesia; postoperative.
Equipment; patient-controlled analgesia systems.

Patient-controlled analgesia (PCA) has become an accepted technique for the provision of postoperative analgesia [1]. Several reliable electronic patient-controlled analgesia systems (PCAS) are now available but they are expensive and considerable capital investment is required if they are to be made available to all patients after surgery.

Baxter have developed a lightweight, nonelectronic disposable PCAS which has been shown to provide satisfactory analgesia [2]. However, a direct comparison of this device with an electronic PCAS has not been made. Therefore, we compared the performance of the Baxter disposable PCA device with the Graseby electronic PCA syringe pump in patients after surgery.

Methods

Female patients (ASA grades 1–2, aged 26–59 years) undergoing major gynaecological surgery were studied. All patients gave written informed consent to the study which was approved by the local Ethics Committee.

Patients were allocated randomly to receive postoperative analgesia with either the Baxter disposable or the Graseby electronic PCAS. The disposable device has been described previously [2] and consists of two components: a balloon reservoir constant infusion device [3] which is connected by microbore tubing to a patient-control module worn around the wrist. This is attached to the intravenous infusion line via a nonreturn valve. The patient-control module contains a small bladder with a capacity of 0.5 ml. As the infusor delivers 5 ml.h^{-1}, the bladder fills in 6 min and, when analgesia is required, the patient presses a button on the face of the PCA device. This releases a clamp and the contents of the bladder are delivered to the patient.

At a pre-operative interview, patients were allocated randomly to receive postoperative analgesia with the Baxter or Graseby device. They were instructed in the use of the device and in the visual linear analogue scoring (VAS) method that was to be used for assessment of pain and sedation. Each linear analogue comprised a 10 cm unmarked line, the ends of which denoted the extremes of the variables in question, i.e. no pain, worst possible pain; wide awake, unable to stay awake.

All patients were premedicated with temazepam 20 mg given orally 1 h before surgery. Anaesthesia was induced with thiopentone 3–4 mg.kg^{-1} and tracheal intubation was facilitated by vecuronium 0.1 mg.kg^{-1}. The lungs were ventilated with 66% nitrous oxide and enflurane in oxygen and morphine 0.2 mg.kg^{-1} was given to supplement anaesthesia.

In the recovery room, the PCAS was attached to the intravenous cannula via a nonreturn valve. The Graseby PCAS was set to deliver a dose of morphine 1 mg with a

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Table 1. Patient characteristics; Mean (SD). There were no significant differences.

	PCAS Group	
	Baxter ($n = 15$)	Graseby ($n = 15$)
Age; years	42.0 (12.0)	41.7 (7.4)
Weight; kg	62.3 (11.9)	64.8 (12.4)
Height; cm	162.0 (7.3)	160.1 (6.4)
Duration of surgery; min	66.0 (21.9)	80.1 (22.7)

Table 2. Mean (SEM) intra- and postoperative dose of morphine (mg). There were no significant differences.

	PCAS Group	
	Baxter ($n = 15$)	Graseby ($n = 15$)
Intra-operative	13.2 (1.9)	10.2 (0.4)
Postoperative	35.1 (8.5)	35.7 (6.6)

lockout time of 6 min. A solution of morphine 2 mg.ml^{-1} was prepared and attached to the Baxter device which gave a 0.5 ml bolus dose of 1 mg with an effective lockout time of 6 min. Prochlorperazine 12.5 mg intramuscularly was given for nausea as required.

Visual analogue scores for pain and sedation were measured at 6, 24 and 30 h after commencement of PCA. At the end of the 30 h study period, pain relief and acceptability of the method was assessed by a verbal three-point scoring system: 'good', 'adequate', 'poor' for pain relief and method of delivery; 'yes', 'perhaps', 'no' for willingness to use again.

At the end of the study, solution was aspirated from the Baxter disposable device and the volume administered to the patient was calculated. This was compared with the value given by the volume indicator on the device.

Data were analysed by unpaired Student's *t*-test, Wilcoxon rank sum test and Chi-squared test with Yates' correction as appropriate.

Results

A total of 32 patients were studied. The results of one patient in each group were excluded from analysis because of protocol violations. Patients were well matched for age, height and weight (Table 1).

There were no significant differences between the groups with respect to mean doses of morphine administered in the operating theatre or in the 30 h postoperative period (Table 2).

Table 3. Number of prochlorperazine doses administered intramuscularly. There were no significant differences.

Doses (n)	Baxter (n)	Graseby (n)
0	9	5
1	0	4
2	4	4
3	2	0
>3	0	2

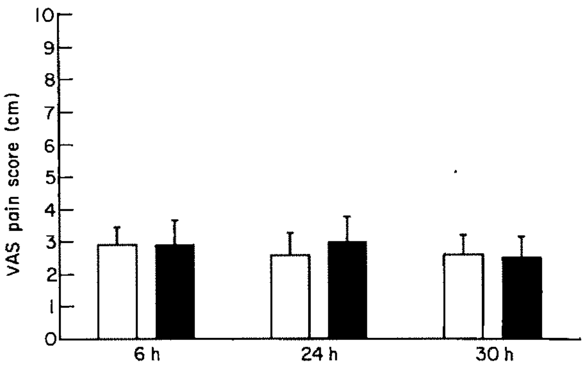

Fig. 1. Mean (SEM) visual analogue pain scores (cm). No significant differences. □, Baxter; ■, Graseby.

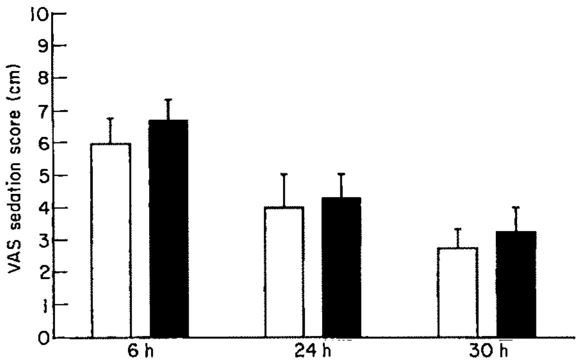

Fig. 2. Mean (SEM) visual analogue sedation scores (cm). No significant differences. □, Baxter; ■, Graseby.

There were no differences between the groups in the requirements for prochlorperazine ($p = 0.058$; Table 3) or in the VAS scores for pain and sedation (Figs 1 and 2).

The verbal three-point scoring system for pain relief and method of delivery are shown in Table 4. Two patients in the Graseby group rated the method and quality of pain relief as 'poor' and three stated they would not want to use the technique in future. This was not found in the Baxter group but the differences were not statistically significant.

The Baxter device tended to underestimate the volume of morphine administered. The mean difference between the measured volume and the value given by the device was

Table 4. Three-point verbal scoring system for overall analgesia, satisfaction with method and willingness to repeat technique. There were no significant differences.

	Baxter (n)	Graseby (n)	p
Pain relief			
Good	12	11	
Adequate	3	2	
Poor	0	2	0.32
Method			
Good	13	13	
Adequate	2	0	
Poor	0	2	0.13
Future use			
Yes	14	12	
Perhaps	1	0	
No	0	3	0.12

2.6 ml. The range was an underestimate of 7.3 ml to an overestimate of 2.7 ml.

Discussion

In this study, we have found no significant differences between the Graseby electronic and the Baxter disposable PCAS with respect to performance and acceptability in patients after major gynaecological surgery.

Lack of flexibility can be a disadvantage with the disposable system. For example, if a larger bolus dose is required, a new infusion device with a greater concentration of morphine must be prepared. However, in this study, it was not necessary to adjust the regimen and all patients received satisfactory analgesia. It is not possible with this device to monitor the precise amount of morphine administered to the patient. The adhesive scale which attaches to the infusion device gives only an approximate indication. We found that this may underestimate by 7.3 ml or overestimate by 2.7 ml. However, in clinical use where patients control their own administration and regular observations are taken by the nursing staff, this is not likely to be a significant problem.

We have found that the most attractive feature of the disposable system is its simplicity and convenience. Every patient in the study found the device acceptable whilst two patients described the Graseby PCAS technique as poor, but these differences were not significant statistically. We believe that the disposable device is less prone to user error, as the regimen cannot be changed once commenced and the device allows better mobility for the patient without interruption of pump function.

In summary, we have found that the Baxter disposable PCAS performed as well as a Graseby electronic PCAS in patients after major gynaecological surgery. It may be of benefit to investigate the performance of this device in other situations.

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Anaesthesia, 1992, Volume 47, pages 163–165

Effects of timolol ophthalmic solution on the intra-ocular pressure rise induced by suxamethonium and tracheal intubation

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Summary

Thirty patients received topical application of either timolol ophthalmic solution 0.25%, or normal saline, 2 h before elective ophthalmic surgery in a double-blind study. The responses to suxamethonium and tracheal intubation were compared by measuring intra-ocular pressure before induction of anaesthesia, 1 min after administration of thiopentone 2–4 mg.kg^{-1}*, 1 min after administration of suxamethonium 1 mg.kg*$^{-1}$*, and 1, 2.5 and 5 min after tracheal intubation. There was no significant difference between the groups.*

Key words

Anaesthesia; ophthalmic.
Complications; increased intra-ocular pressure.
Neuromuscular relaxants; suxamethonium.
Sympathetic nervous system; pharmacology, timolol.

Concern about potentially damaging rises in intra-ocular pressure (IOP) associated with suxamethonium [1] and tracheal intubation [2] is attested by the variety of methods employed to attenuate these increases [3–9]. None has been shown to be entirely satisfactory. The suggestion that increases in IOP are mediated by β-adrenergic transmission [10] has been supported by a study which examined the effects of pretreatment with an intravenous

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Table 1. Demographic data presented as mean (SD).

	Timolol ($n = 15$)	Saline ($n = 15$)
Age (years)	58 (20)	50 (18)
Weight (kg)	78 (14)	70 (11)
Resting IOP (mmHg)	14 (3)	15 (4)
Baseline MAP (mmHg)	112 (11)	104 (16)
Baseline HR (beats.min^{-1})	70 (12)	75 (16)

IOP, intra-ocular pressure; MAP, mean arterial pressure; HR, heart rate.

β-adrenoceptor antagonist [11], but systemic effects may limit the usefulness of the technique. Topical application of timolol reduces IOP in glaucomatous eyes [12] and the present study was undertaken to assess IOP changes after pretreatment with topical timolol, whose systemic effects after a single dose could be expected to be minimal.

Methods

The study was approved by the District Medical Ethics Committee. Thirty selected adults of ASA categories 1 or 2 and scheduled for elective ophthalmic surgery consented to take part. Hypersensitivity to timolol, bronchial asthma or cardiac conduction abnormalities excluded patients from the trial, as did concurrent therapy with β-adrenoceptor blockers, pre-existing raised IOP and previous intra-ocular surgery on either eye.

Patients were assigned randomly to receive either timolol 0.25% ('Timoptol' Merck, Sharp and Dohme Ltd) or saline ophthalmic solution 0.9%, one drop into the nonoperated eye before premedication with oral diazepam 5–10 mg 2 h before surgery. Anaesthesia was induced with thiopentone 2–4 mg.kg^{-1}, and suxamethonium 1 mg.kg^{-1} was administered 1 min later. The vocal cords were sprayed under direct laryngoscopy with lignocaine 100 mg and the trachea was intubated. Anaesthesia was maintained with nitrous oxide 65% in oxygen 35%, and enflurane 1%. Ventilation was controlled using a Bain breathing system; the fresh gas flow rate was adjusted to maintain the end-tidal carbon dioxide concentration at 5%. A smooth transition to neuromuscular blockade with atracurium 0.5 mg.kg^{-1} was ensured by the use of a Bard peripheral nerve stimulator which delivered supramaximal train-of-four stimuli to the ulnar nerve at the wrist. Other monitoring included automatic blood pressure recording (Critikon 'Dinamap' 1846 SX), electrocardiography and continuous end-tidal carbon dioxide concentration (using a calibrated Datex 'Normocap' analyser, Vickers Medical Ltd, UK).

IOP was measured in the nonoperated eye using a noncontact air impulse tonometer (Keeler 'Pulsair') [13]. The mean of four readings was taken on each occasion. Measurements were made before the instillation of eye drops, immediately before induction of anaesthesia, 1 min after administration of thiopentone, 1 min after administration of suxamethonium, and 1, 2.5 and 5 min after tracheal intubation.

Pre-induction values were used as the baseline for subsequent statistical analysis. Changes in IOP, mean arterial pressure (MAP) and heart rate (HR) within groups were analysed by a cross-classified two-way analysis of variance with a nested factor for patients within groups. Results which showed a significant group effect ($p < 0.05$) with respect to mean change were analysed subsequently by a two-sample *t*-test.

Results

The two groups were comparable in respect of age and weight, baseline IOP and baseline heart rate and arterial pressure (Table 1). Surgical procedures included cataract extraction, dacrocystorhinostomy and squint correction in both groups.

The mean IOP in both timolol and saline groups was significantly lower than baseline 1 min after administration of thiopentone ($p < 0.001$; Table 2). There was no change in IOP after administration of suxamethonium in the timolol group but there was a significant increase 1 min after intubation ($p < 0.005$). In patients who received saline, mean IOP peaked 1 min after administration of suxamethonium before falling significantly below baseline 5 min after tracheal intubation ($p < 0.001$). There was no difference between the timolol and saline groups in respect of mean changes in IOP.

In both timolol and saline groups the heart rate increased above pre-induction values following induction of anaesthesia ($p < 0.005$), after administration of suxamethonium ($p < 0.005$), and 1 min ($p < 0.005$) and 2.5 min after tracheal intubation ($p < 0.005$; Table 2). There was no difference between the groups. Mean arterial pressure increased significantly 1 min after intubation in both the timolol ($p < 0.001$) and saline ($p < 0.001$) groups. There was no difference between the groups.

Table 2. Changes in intra-ocular pressure, mean arterial pressure and heart rate, presented as mean (SD).

				After tracheal intubation		
	Pre-induction	1 min after thiopentone	1 min after suxamethonium	1 min	2.5 min	5 min
IOP (mmHg)						
Timolol ($n = 15$)	14 (3)	9 (2)§	15 (4)	18 (6)*	14 (5)	12 (6)
Saline ($n = 15$)	15 (4)	10 (3)§	17 (5)	16 (5)*	12 (5)	9 (3)‡
MAP (mmHg)						
Timolol ($n = 15$)	112 (11)	107 (14)	110 (20)	138 (20)‡	125 (22)	104 (25)
Saline ($n = 15$)	104 (16)	97 (10)	112 (27)	125 (24)‡	116 (27)	92 (19)
HR (beats.min^{-1})						
Timolol ($n = 15$)	70 (12)	79 (15)†	83 (15)†	90 (11)†	83 (13)†	76 (13)
Saline ($n = 15$)	75 (16)	85 (11)†	92 (12)†	96 (20)†	92 (18)†	80 (15)

* Significant difference from baseline ($p < 0.005$); † significant difference from baseline ($p < 0.01$); ‡ significant difference from baseline ($p < 0.001$).

IOP, intra-ocular pressure; MAP, mean arterial pressure; HR, heart rate.

No adverse or systemic effects were identified after administration of either of the ophthalmic solutions.

Discussion

Surges in IOP under anaesthesia may imperil an eye already threatened by injury or disease. Diverse approaches to the problem have included pretreatment with nondepolarising muscle relaxants [5], small 'self-taming' doses of suxamethonium [6], and the use of drugs as dissimilar as diazepam [7, 8], hexafluorenium [14], acetazolamide [15], propranolol [11] and intravenous lignocaine [3, 9]. The mechanisms by which IOP is thought to rise acutely during anaesthesia relate primarily to external compression of the globe and to changes in intra-ocular volumes of aqueous humour and blood. Suxamethonium is believed to increase IOP both by causing contracture of extra-ocular muscles [16] and by dilating choroidal blood vessels [17, 18]. Laryngoscopy and tracheal intubation may increase IOP via a direct reflex response with a rapid increase in central venous pressure [19].

The present investigation of timolol was based on the suggestion that IOP increases may be mediated in part by β-adrenergic pathways [11, 12]. Pretreatment with intravenous propranolol may limit rises in IOP, but it is not clear whether this is a direct effect or is a secondary result of attenuating increases in the rate-pressure product [12]. The potential for cardiovascular depression restricts the usefulness of such a technique [12]. Topical β-blockers have been used successfully in the treatment of glaucoma, where the unopposed α-vasoconstriction in uveal vasculature leads to a reduction in aqueous humour formation [20]. However, we were able to demonstrate no difference between saline and timolol in respect of acute increases in IOP. Moreover, there was no difference between groups in pre-anaesthetic IOP which suggests that topical administration of a single dose of timolol 0.25% does not reduce the pressure in normotensive eyes. A large dose might have been more appropriate, although the inability of the drug to prevent acute rises in IOP is due probably to its failure to block more than one of the mechanisms by which pressure is increased. It may be that in combination with, for example, pretreatment with a nondepolarising muscle relaxant, the technique would be more effective. IOP did fall markedly following the administration of thiopentone, providing confirmation of a response which was first described in 1959 [21]. This ocular hypotensive effect may explain the finding that IOP following administration of suxamethonium did not increase significantly above baseline in either group. The haemodynamic data showed no evidence of systemic β-adrenoceptor blockade; baseline heart rate was similar in the two groups, as were heart rate changes during the study period.

Acute IOP increases are probably of greater clinical significance in eyes in which the pressure is chronically elevated, and which may respond differently during anaesthesia. There remains scope for investigating the IOP response in patients on long-term treatment with topical β-adrenoceptor antagonists, and for examining the value of combination techniques which aim to block all the pathways by which acute rises in IOP may be mediated.

Acknowledgments

The authors wish to thank Miss P. Ronan of Merck, Sharp and Dohme Ltd. for financial support, and Dr J. Kelly, consultant anaesthetist at St. Paul's Eye Hospital, for her help with this study.

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Blood pressure cuff changeover in paediatric anaesthesia

A recent letter (*Anaesthesia* 1991, **46:** 898) proposed the use of two three-way taps to switch between paediatric and neonatal hoses/cuffs when using the Dinamap blood pressure monitor. I believe such a practice to be potentially dangerous for the following reasons: (1) It would become possible to switch out the transducer from the pump circuit enabling a cuff to be overinflated without protection from the normal safety system. (2) The criteria for cuff sizing (neonatal/adult/paediatric) which is based on tube length may be impaired resulting in inappropriate selection of alarm and overpressure parameters. (3) Partial switching of taps could impair inflation rates and data transmission which could affect the results. (4) The use of two cuffs/air hose assemblies connected to a single unit could result in confusion over which patient has generated the data.

I would like to point out that Critikon do not recommend use of a three-way tap and advise that this technique should not be used.

Business Manager Patient Monitoring, C. Sethna
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A reply

We thank Mr Sethna for his useful comments about our letter. Points 1 and 3 would only occur if the three-way taps were incorrectly or only partially turned. All equipment that has the potential for human error should be used with care and we recommend constant vigilance to avoid such mishaps. We were surprised by point 2 as we have used the system described for over a year without any mishap or doubt about the accuracy of pressures obtained. We agree that simultaneous connection to two patients as suggested by point 4 is unsafe and never intended that the equipment should be used in this way. Although no modification to anaesthetic equipment should be undertaken lightly, the system we described has been useful in our practice.

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Vaporizer tilt — a plea for a level approach

We were interested to read of the method to stop excessive tilting of vaporizers (*Anaesthesia* 1991; **46:** 152). We have encountered the same tilting problems, not only with our Selectatec fittings, but also with back bars with a single vaporizer mounting. The mean angle of tilt of the back bars and vaporizers on all our anaesthetic machines ($n = 20$) was 5.22° (range 0° − +12°) for backbars and 5.05° (−1° − +11°) for vaporizers. Overall, eight vaporizers and back bars had a tilt of 7° or greater. Given the internal dimensions of the Tec 3 vaporizer and the mathematical equations for the volume of (a) a truncated right circular cylinder and (b) a segment of a right circular cylinder, we calculated the volume of free fluid (excluding wick) within the vaporizer for varying angles of tilt and varying fluid heights in the vaporizer window (Fig. 1). This figure quantifies how a vaporizer that is progressively tilted gives the illusion of containing more fluid than it truly does.

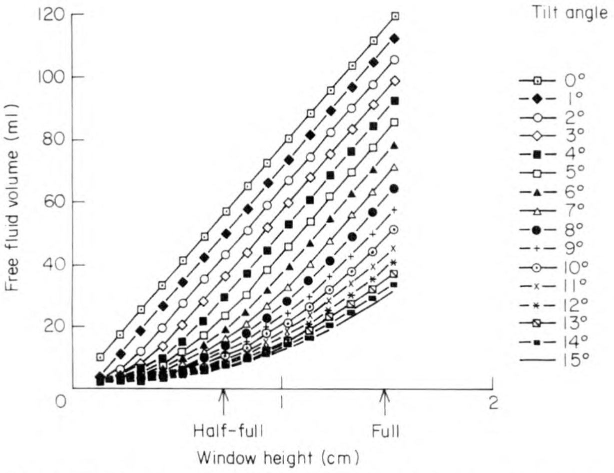

Fig. 1. Fluid volume in vaporizer sump at various angles of tilt.

We investigated the performance of upright vaporizers mounted on tilted back bars using a Siemens Gas Monitor 120 and were alarmed to note that we detected no vapour when the back bar was tilted at 12°. This was caused by the poor connection between the tilted back bar and the erect vaporizer at this angle. While we congratulate Saunders and Nesling on their ingenuity in trying to deal with this problem, we would caution against the introduction of such a system unless the original problem i.e. the tilting of the back bar is also corrected. Furthermore, while the new British Standard for Anaesthetic and Analgesic machines introduces the concept of maximum and minimum levels marked on a liquid level indicator in vaporizers [1], such a standard does not directly deal with the primary problem of back bar tilt. In a tilted vaporizer the rate of fall in window height increases rapidly as the vaporizer empties; this may well lead to the minimum level mark being passed more quickly than an otherwise preoccupied anaesthetist may notice. Indeed, of all their equipment, anaesthetists pay the least attention time to their vaporizer [2].

We would urge that the maintenance of anaesthetic equipment should include the routine measurement (Figs 2 and 3) and correction of tilt of both back bar and vaporizer. Maintenance standards and manufacturers design specifications should be updated to address this serious problem.

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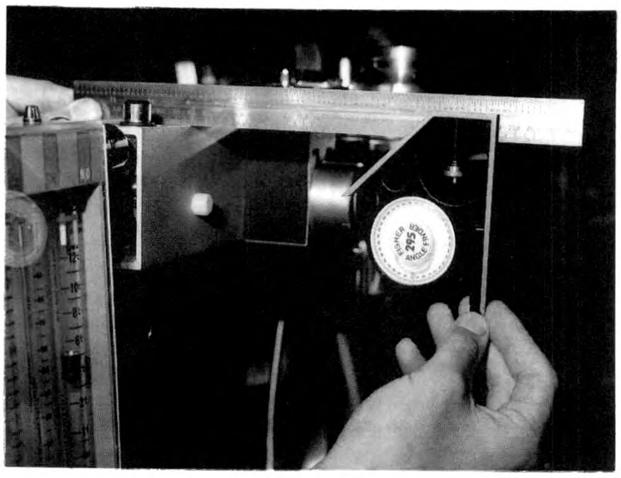

Fig 2.

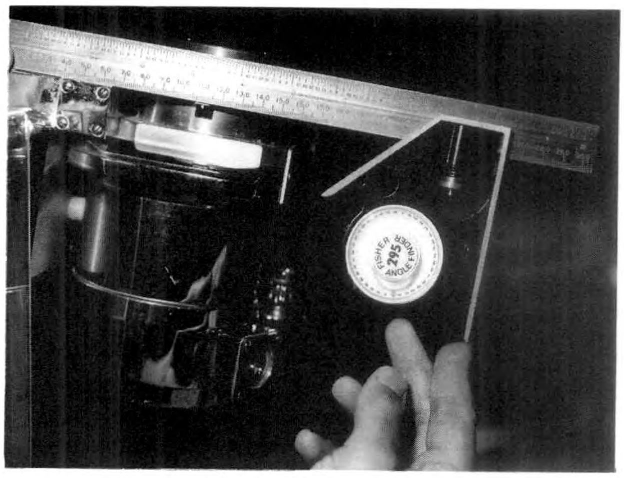

Fig. 3.

Fatal intra-operative fat embolism

An 85-year-old female was paralysed and her lungs ventilated under general anaesthesia for a total hip replacement. Monitoring consisted of ECG, automatic noninvasive blood pressure, end-tidal carbon dioxide and pulse oximetry. Ninety minutes after induction, the arterial blood pressure was recorded as 230/170 mmHg, whereas 3 min previously it had been 115/65 mmHg. All other monitors showed normal readings at this stage and the patient looked pink and well perfused; the blood pressure was re-checked and still found to be very high. The end-tidal carbon dioxide monitor then showed a fall from 4 kPa to 2 kPa and the heart rate slowed from 66 to 37 beats.min^{-1}. A desaturation from 97% to 85% accompanied these changes. The patient was now clinically hypoxic and she was turned supine to allow cardiac massage. A right internal jugular line was inserted and the central venous pressure was 10 cmH$_2$O. After 30 min, attempts at resuscitation were abandoned. Subsequently postmortem examination established the cause of death to be fat embolism.

Fat embolism in its classical form is not uncommon after injury to long bones [1]. If large amounts of fat reach the right ventricle, then right heart failure can occur and the syndrome is described as fulminant [2]. Cardiac arrest due to fat embolism under anaesthesia has been described [3] and more recently, under anaesthesia for closed manipulation of the hips [4]. However, its presentation in this situation remains rare.

It seems there are two routes for fat emboli to reach the systemic circulation [5]. Minor embolism may occur directly through the pulmonary circulation, but when this route is blocked the emboli may be diverted through the pulmonary–bronchial anastomoses. Fat reaching the cerebral circulation may set up a reflex systemic vasoconstriction accounting for the hypertension seen and a reflex pulmonary vasoconstriction resulting in an increase in alveolar deadspace and hypoxaemia [6]. This decrease in pulmonary blood flow may further divert emboli into the systemic circulation. It would seem from this case that relatively little fat is needed as there were no clear signs of right heart failure.

Fulminating fat embolism is notoriously difficult to treat and when it occurs under anaesthesia the situation is complicated further. Respiratory support with tracheal intubation and ventilation is obviously required. Treatment of the cardiovascular derangement should be aimed at treating a hypoxic myocardium. If one accepts that pulmonary vasoconstriction plays a large part, not only in the production of hypoxaemia but also in shunting blood and more fat emboli into the systemic circulation, then perhaps treatment should be aimed at pulmonary vasodilation with glyceryl trinitrate or a similar agent.

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Diamorphine toxicity

The administration of ever increasing doses of opioid to a patient in obvious pain may not be appropriate management; I should like to report an unusual complication of diamorphine given in high doses.

A 33-year-old woman with a diagnosis of anaplastic carcinoma of the cervix (Stage IV A) was admitted to Ashgate Hospice for symptom control. On admission the patient was taking 350 mg twice daily of a slow release oral morphine preparation (MST Continus: Napp) for a continuous pelvic pain and acute myalgia from intense involuntary muscle spasms which affected her limbs and her facial muscles equally. She had no history of epilepsy or eclampsia. During the twitching episodes, the patient remained conscious and was not incontinent of either urine or faeces. Over the next few days, the painful myoclonic spasms lasted longer and became more frequent, but some relief was obtained by increasing the oral MST to 350 mg three times a day. However, the patient soon became exhausted by pain and lack of sleep and was sedated with chlormethiazole 0.8% by infusion. A syringe driver was used to deliver a mixture of midazolam and diamorphine subcutaneously in place of oral medication.

The twitching appeared similar in some respects to the extrapyramidal movements produced as a side effect to some antiemetics, but there was no hypertonia or tremor and the patient's movements were quite normal between the twitching episodes. All antiemetics were withheld temporarily with no improvement.

Her subcutaneous injection sites became markedly inflamed and the pain continued unabated, so a syringe driver was used to infuse diamorphine and midazolam intravenously and ensure good plasma levels of these drugs. By the 10th day of admission she was receiving 150 mg midazolam and 4 g diamorphine in 24 h by the pump, clonazepam 4 mg intramuscularly in 24 h and up to 100 ml.h^{-1} of chlormethiazole 0.8%. The twitching became worse until finally she had a grand mal convulsion. It was felt by the Hospice staff that the twitching had become worse when the diamorphine dose had been increased, so the infusion was stopped.

Her pelvic pain was successfully controlled with an infusion of bupivacaine 0.125% at 6 to 12 ml.h^{-1} through a thoracolumbar epidural catheter. The twitching subsided and eventually ceased over the next 48 h and she required sedation over the next few days only to reduce the symptoms of acute opioid withdrawal.

Martindale's pharmacology text [1] suggests that morphine and some opioids can produce muscle rigidity;

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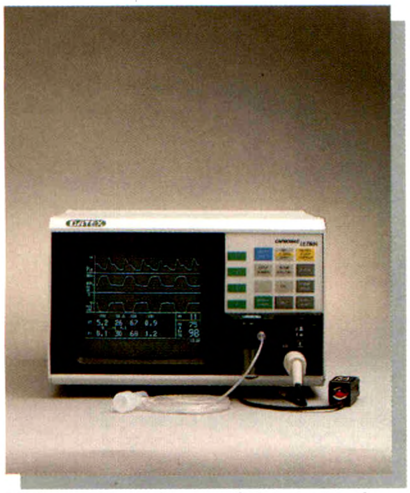

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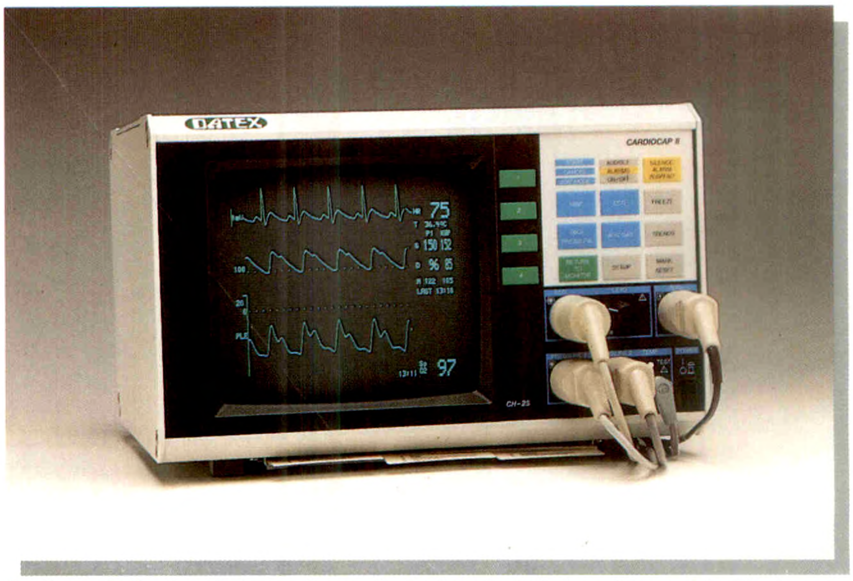

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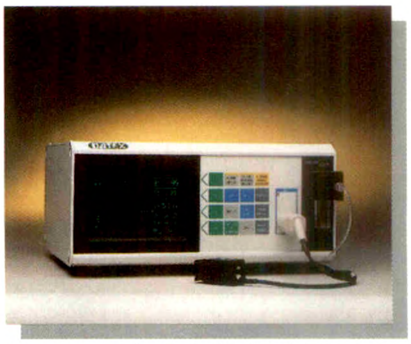

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however, it is hypertonia rather than muscle twitching that occurs. Glavinia and Robertshaw described a case of myoclonic spasm in a 59-year-old woman who received a bolus of 3 mg of intrathecal morphine for intractable pain [2] while Jayawardena and Hill described a case of myoclonus in a 65-year-old woman 24 h after discontinuing a diamorphine infusion into the epidural space [3].

In both the previously reported cases of myoclonic spasms following the administration of morphine and diamorphine, the drugs had been infused spinally in much smaller doses. The 100-fold difference in dose before the development of myoclonus is probably related to the concentration gradient between the intravenous and cerebrospinal compartments, this being a function of a lipid solubility of diamorphine. Terminally ill patients at the Hospice commonly receive comparable doses of diamorphine and morphine to that initially given to this patient without developing myoclonic spasms, but ureteric obstruction leading to chronic renal insufficiency may have accelerated central neuronal toxicity in this patient as it would impair excretion of unconjugated active morphine.

Ashgate Hospice D. TURNER
Chesterfield

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Venous/arterial blood management protection system

We have recently assessed the function of the venous/arterial blood management protection system (VAMP) manufactured by Baxter and have been impressed with its simplicity and ease of operation. This disposable system, consisting of a length of pressure monitoring tubing, reservoir, shut-off valve and blood sampling site (Fig. 1) is attached distally to a pressure transducer and allows a convenient method for the periodic withdrawal of blood samples. It may be used with arterial, pulmonary artery or central venous catheters.

Five millilitres of heparinised blood/saline mixture are drawn from the patient into the VAMP reservoir over 3–5 s using the reservoir plunger. After turning the shut-off valve, undiluted blood samples are drawn from the sampling site using a guarded needleless cannula attached to either a syringe or a direct draw blood transfer unit (BTU). If the latter is used, individual vacuumed blood sample tubes may be attached directly to the BTU for filling. Following completion of blood sampling, the shut-off valve is re-opened and the reservoir volume slowly returned to the patient using firm, even pressure on the reservoir plunger. The sampling site is cleansed using an alcohol swab before and after sampling.

The VAMP system may be useful in an Intensive Care Unit for several reasons. Firstly, it is likely to reduce the risk of sampling-related anaemia which has been reported, particularly in children [1, 2]. Although some of the reduction in haemoglobin may be related to the removal of the blood samples themselves, it is often the case that the initial volume of blood/heparinised saline mixture removed from the patient is discarded. The use of a closed sampling system will reduce this effect. Secondly, the absence of potentially messy and infected three-way taps as sampling points for blood, and the use of the VAMP sampling system, may reduce the risk of catheter-related sepsis. Finally, the use of needles during blood sampling is potentially hazardous to health workers [3]; the fact that the VAMP system employs a needleless sampling method will reduce the incidence of needlestick injuries.

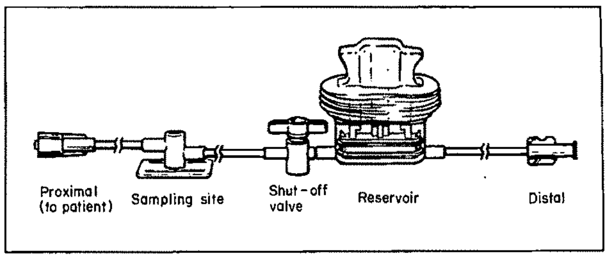

Fig. 1. Baxter venous/arterial blood management protection system (VAMPTM).

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Dural puncture and depth of the extradural space

We read with interest the article by Sutton and Linter (*Anaesthesia* 1991; **46:** 97–8) concerning the relative risk of dural puncture as a function of the depth of the extradural space. This study prompted us to examine our own data about the same subject. Since 1989, we have recorded prospectively, and collected on standardised forms, the technical characteristics of all the epidurals performed in obstetric patients, either for labour or for elective Caesarean section. The depth of extradural space was one of the collected items, as well as the occurrence of dural

Table 1.

Depth of extradural space (cm)	Number of extradural procedures (and %)	Number of dural punctures	% of total extradural procedures	Risk factor
Shallow (2–4)	308 (14.9%)	4	1.30%	3.4
Normal (4–6)	1565 (75.7%)	6	0.38%	1
Deep (6–9)	195 (9.4%)	0	0%	

puncture. A total of 2068 lumbar extradural procedures were performed from the 1 January 1989 to 31 December 1990. Using the same categories of distance from skin to extradural space as Sutton and Linter, we found nearly the same results as indicated in the Table. The only difference (a 0% incidence of dural puncture in the 'deep' group) is clearly a chance effect as the absolute number of epidurals performed in this group is too low to assess a risk which may be as low as 0.5%.

In contrast, it is interesting to see that the distribution of the depth of the extradural space, as well as the relative risk of dural puncture between the 'shallow' group and the 'normal' group are similar on both sides of the Channel!

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Diclofenac for pain caused by gemeprost pessaries

There has been an increased interest in the use of nonsteroidal anti-inflammatory drugs for postoperative analgesia. Recently we used intravenous diclofenac in two patients who had received gemeprost pessaries before suction termination of pregnancy. Many women complain of period-type pain with these pessaries, but both these women were crying with pain, which had persisted after the operation. Diclofenac 75 mg was diluted to 20 ml and administered intravenously, within 2–3 min the pain was completely relieved.

As the pain was prostaglandin mediated, this appears to provide a logical choice of analgesia, provided there are no specific contraindications. Normally we would prescribe it orally. These two women were so distressed that we considered administration of an opioid. Intravenous nonsteroidal anti-inflammatory drugs can provide rapid, profound analgesia without sedation in these day-care patients.

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'Field' anaesthesia for an ICU procedure

We read with interest the report on percutaneous dilational tracheostomy by Dr Bodenham and his colleagues (*Anaesthesia* 1991; **46:** 570–2). The technique is being employed increasingly as a bedside procedure in our intensive care unit (ICU) since it has a number of advantages over conventional tracheostomy: the procedure can be performed without moving an unstable patient whose lungs are being ventilated to and from the operating theatre, monitoring does not need to be interrupted for transport, valuable operating theatre time is not required, and costs may be reduced.

One concern is that the procedure will not be treated with the respect it deserves simply because it is carried out at the bedside. All the precautions taken for conventional tracheostomy should be similarly observed during percutaneous dilational tracheostomy on the ICU. A skilled anaesthetist, separate from the operator, is required to maintain anaesthesia and muscle relaxation, and to control the airway and ventilation during the procedure. One requirement of the procedure is for the tracheal tube to be withdrawn to the level of the vocal cords to allow passage of the dilators. Artificial ventilation is best provided manually using a self-inflating or Waters' bag. This allows the anaesthetist to compensate for the change in resistance and the air leak associated with the insertion and withdrawal of successive dilators. Anaesthesia can then be provided intravenously by infusion, as described by Dr Bodenham, or by repeated intravenous bolus administration. The infusion technique requires the preparation of two infusions and is expensive of nursing time, drugs and disposable equipment unless the patient is currently receiving these drugs for sedation. Intermittent bolus injection of the drugs may cause marked swings in blood pressure, and distracts the anaesthetist from controlling the airway and ventilation. Inhalational anaesthesia is an attractive alternative because anaesthesia and airway management are provided simultaneously, but usually requires a bulky anaesthetic machine to be crammed into an already overcrowded bedspace.

In this ITU we have used a drawover system to overcome these difficulties. This is based on the Triservice apparatus and consists of a single Oxford Miniature Vaporizer containing isoflurane connected to resevoir tubing at its inlet allowing oxygen enrichment, and to a self-inflating bag (Ambu) and patient valve. Scavenging during this short procedure was achieved by a length of tubing from the expiratory port of the valve to an outside window. This technique allows safe and reasonably inexpensive anaesthesia using compact equipment, while allowing attention to be directed solely at the control of ventilation: surely an indication for using 'field' anaesthesia in a hi-tech environment?

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Failure of Ohmeda Tec 4 Safety Interlock

The operator's manual for the Tec 4 Vaporizer [1] states that the safety interlock 'require(s) that the vaporizer is locked onto the manifold before it can be turned on.' However, in a recent incident a patient awoke in the operating theatre, before the start of surgery, because of a failure of this interlock.

Anaesthesia was induced in an unpremedicated 30-year-old male with thiopentone and his trachea intubated after relaxation with suxamethonium. He was transferred to the operating theatre once spontaneous respiration had resumed. An Ohmeda Excel 410 anaesthetic machine was set to deliver oxygen 2 l.min^{-1} and nitrous oxide 4 l.min^{-1} and the Tec 4 vaporizer 2% isoflurane, via a standard circle breathing system as supplied with this machine. The machine and breathing system had been checked before the start of the list in accordance with the AAGBI guidelines [2]. It was noticed immediately that the reservoir bag failed to fill and that the patient's depth of anaesthesia was inadequate. A rapid check of the anaesthetic machine and circuit revealed no disconnections; the vaporizer was locked into position at an appropriate concentration setting and with adequate volatile agent content.

Senior assistance was called for and the spontaneously breathing patient was disconnected from the anaesthetic apparatus. He was awakening rapidly and was therefore turned into the left lateral position and his trachea extubated. The patient was disorientated but otherwise well; his oxygen saturation had remained normal throughout with only minimal increases in heart rate and systolic blood pressure.

We turned our attention back to the equipment once we had assured the patient's safety. The vaporizer in use had been changed between cases, and although quite firmly attached to the Selectatec manifold, locked, turned on, and with safety interlock engaged, was in fact slightly tilted, allowing the gas flow to vent to atmosphere at the rear of the machine (Fig. 1). Subsequent investigation revealed that the locking lever spindle had a splayed end which allowed all the safety mechanisms to be engaged despite malposition (Fig. 2).

This misalignment was not noticed on rapid check of the equipment, and only became apparent on careful inspection and back pressure testing of the equipment by a more senior anaesthetist. A further Tec 4 Vaporizer was found to have a similar fault, a total of two out of 17 in this department.

A 1984 Health Notice (Hazard) [3] stated that vaporizers should be level before use. The operator's manual also states that a pressure test should be performed whenever a vaporizer is changed; however, we believe that in practice this is rarely done in the middle of an operating list. The importance of rechecking equipment whenever a component is changed and the close attention which must be paid to the inspection of safety interlock components at servicing has been highlighted in a Safety Action Bulletin [4], published whilst this letter was being written, and we think this incident well illustrates these concerns. Fail-safe mechanisms fail!

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A.J. Hartle
R.E.O. Daum

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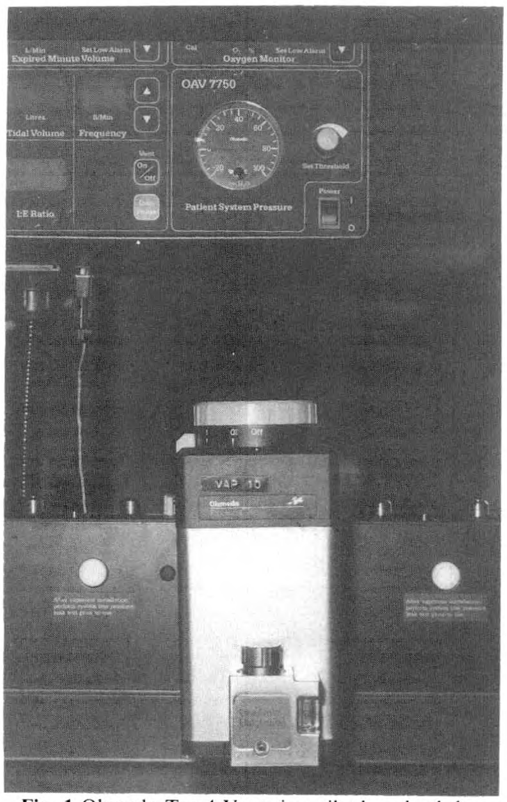

Fig. 1 Ohmeda Tec 4 Vaporizer tilted on back bar.

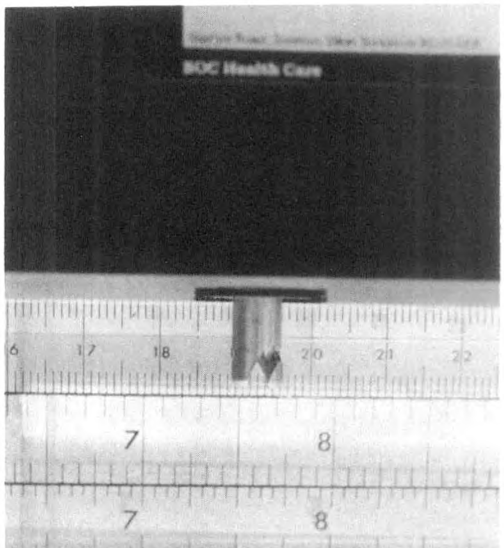

Fig. 2. Splayed end of locking spindle.

Airway mucous plug mimicking diaphragmatic herniation

Classically, airway mucous plugs cause hypoventilation and collapse of the underlying lung [1], although the development of a transient unilateral hyperlucent lung has been described when mucous plugging has been associated with air trapping [2]. We present a case of unilateral subtotal lung collapse secondary to mucous plugging which mimicked post-traumatic herniation of viscera through the diaphragm.

A 48-year-old male was admitted to the intensive care unit for ventilatory support following lung contusion sustained in a road traffic accident. Other injuries included minor facial abrasions, a fractured sternum with anterior mediastinal hematoma (seen on CT scan), bilateral rib fractures and right-sided fractures to the humerus, pubic ramus, acetabulum and the neck and shaft of the femur. Angiography and CT scanning excluded intrathoracic vascular injury, but a perisplenic haematoma raised the possibility of either diaphragmatic or organ injury. Laparotomy revealed only a small laceration to the liver which was sutured. External fixators were used on the long bone fractures.

Initially, high inspired oxygen concentrations and inflation pressures were needed to maintain adequate gas exchange, but these were decreased over the ensuing 72 h without detrimental effect. Figure 1 shows a chest radiograph taken after 48 h. Bilateral rib fractures are evident as is the widened superior mediastinum due to the anterior mediastinal haematoma. Lack of definition of the left hemidiaphragm was believed to be due to the presence of a small pleural effusion since diaphragmatic injury had been excluded at laparotomy. Figure 2 shows a routine chest radiograph taken at 72 h. There had been no significant change in the clinical condition of the patient. The immediate concern was that intra-abdominal contents had herniated through a diaphragmatic tear. Careful inspection of the radiograph, however, shows an abrupt termination of the left air bronchogram with incomplete collapse of the left lung involving upper lobe, lingula and part of the lower lobe. Although the patient is rotated, there is movement of the mediastinum to the left, compatible with collapse. The patient received physiotherapy and after saline instillation, mucous was aspirated from the airway. Figure 3 was taken 30 min later and shows re-expansion of the left lung with small areas of residual atelectasis. The patient continued to make good progress and his trachea was extubated uneventfully on day five. Later radiographs showed a well defined left hemidiaphragm and no further suspicions of traumatic rupture of the diaphragm were raised.

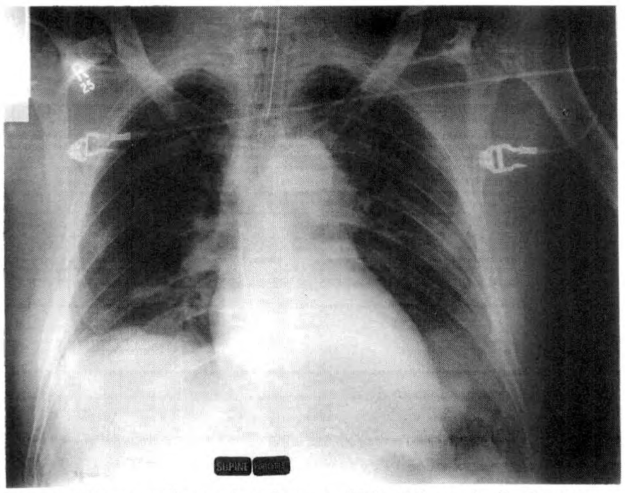

Fig. 1. Chest radiograph taken at 48 h. Bilateral rib fractures, widened mediastinum and indistinct left hemidiaphragm are evident. A tracheal tube and left subclavian line are present.

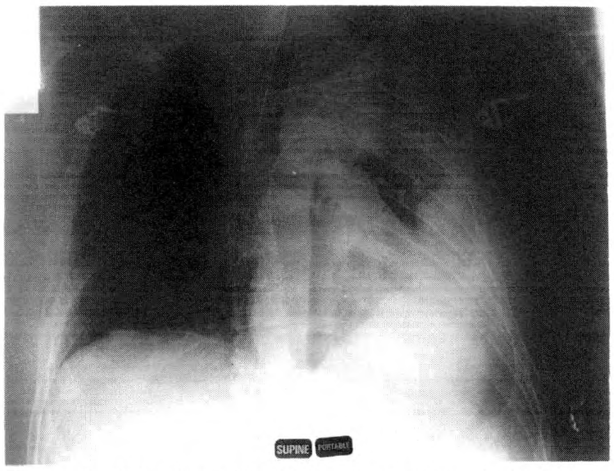

Fig. 2. At 72 h there was abrupt termination of the left air bronchogram with subtotal collapse of the left lung and some shift of the mediastinum to the left.

This case again illustrates the need for adequate airway humidification when natural methods are bypassed. Although inspired gases were constantly humidified utilising a Fisher and Paykel dual servo humidifier, this was inadequate as secretions had thickened to the degree that obstruction and distal collapse had occurred. The patient was stable throughout and as physiotherapy was immediately successful it was deemed unnecessary to perform bronchoscopy. It is interesting that in this patient the collapse mimicked a transdiaphragmatic herniation.

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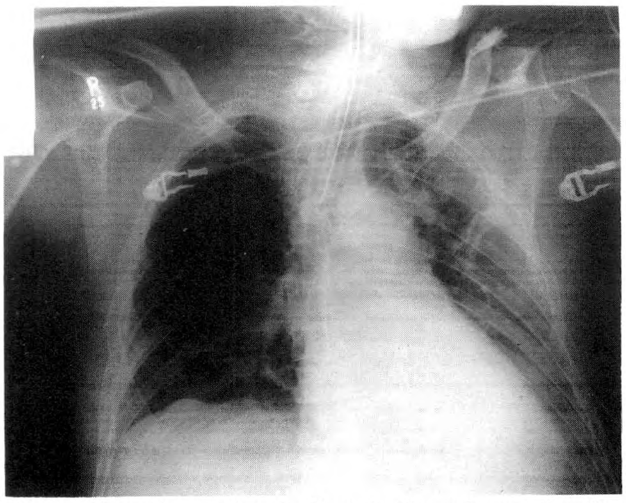

Fig. 3. Thirty minutes after the X ray in Figure 2 was taken the mucous plug had been aspirated allowing the left lung to re-expand. There is some residual atelectasis.

Leaking Datex sampling set for the end-tidal CO_2 monitor

A 60-year-old man weighing 70 kg with mild angina on exertion and no respiratory problems was intubated and his lungs ventilated for lower limb vascular surgery. Hand ventilation was with a Bain circuit in the anaesthetic room, and ventilation of the chest appeared to be normal.

After the transfer to the operating table, the tracheal tube was connected to an Oxford ventilator set at a tidal volume of 700 ml with a frequency of 10 breaths.min^{-1}. The inflation pressure was noted to be low and plateauing at 8 cmH_2O and this was not significantly altered by a temporary increase in the tidal volume to 850 ml. A Wrights respirometer showed the expiratory volume to be 450 ml and hence a leak was sought.

There was an audible hiss during the latter half of inspiration in the region of the tracheal tube, which was not corrected by the addition of further air to the cuff or by a visual check and tightening of the connections between the circuit and the tracheal tube. The catheter mount, angle piece, sampling set and tracheal tube were then changed. A quieter hiss was still audible, with an inflation pressure of 13 cmH_2O, with good expansion of the patient's chest and an expiratory tidal volume of 700 ml.

Testing of the items that had been changed by immersion in a bucket of water whilst connected to a breathing circuit demonstrated an obvious leak from the connector for the end-tidal CO_2 monitor, also called the sampling set. The site of the leak was at the point of passage of the pilot tube into the connector (Fig. 1). The replacement connector was also leaking from the same site, although to a much lesser extent. This was demonstrated by placing some lubricating jelly over the pilot tube entrance site. An identical connector from an adjacent operating theatre was also noted to have a small leak.

The connectors in question are made by Datex Instrumentation Corporation, Helsinki, Finland, and bore the following markings 'Safe and sure, pac date 02.05.1991, 85212-3'. This batch was withdrawn from use from our operating theatre suites, and returned to the distributor (S & W Vickers Ltd) who stated that there had been one other recent complaint of a similar nature. Their impression was in agreement with our experience as outlined above, that the leaks were variable in magnitude. S & W Vickers Ltd are in contact with the manufacturers in Finland with a view to assessing the scale of this problem.

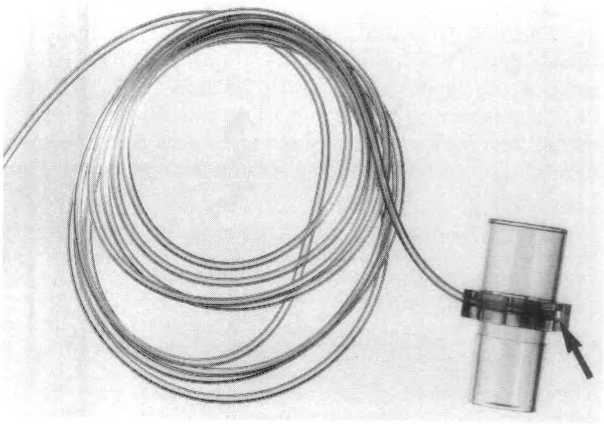

Fig. 1.

Leaks from breathing systems are an important cause of hypoventilation in the paralysed patient. This case demonstrates the continuing importance of the monitoring of the inflation pressure on ventilators, and shows that the single-use sampling set for end-tidal CO_2 monitors is another source of breathing system leakage.

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Dental throat packs and airway protection

A 23-year-old woman presented as an elective day case for the extraction of all four wisdom teeth. Apart from being overweight she was fit and healthy with no previous anaesthetic history. Anaesthesia was induced uneventfully and a 6.5 mm RAE nasotracheal tube passed through the right nostril and into the larynx without difficulty. The patient's lungs were electively ventilated for the procedure. A moist ribbon gauze throat pack was inserted with the aid of Magill forceps.

During the extraction of the left lower 8, the tooth dropped into the mouth. Attempts to retrieve the tooth were unsuccessful. Both intra-oral palpation and examination following laryngoscopy failed to locate the missing tooth. The throat pack was removed and the examination repeated without success. A wide bore suction catheter was passed through the left nostril into the post-nasal space without any resistance. An X ray was taken and revealed the missing tooth lodged high up in the left post-nasal space. (Fig. 1.) The tooth was successfully removed digitally. The patient made an uneventful recovery.

The potential danger of an unaccounted foreign body in the upper airway is obvious. The tooth was misplaced despite the presence of a throat pack. This incident illustrates the need to place the throat pack carefully so that it should not only absorb the blood, secretions and debris associated with dental surgery but also offer some protection to the postnasal space.

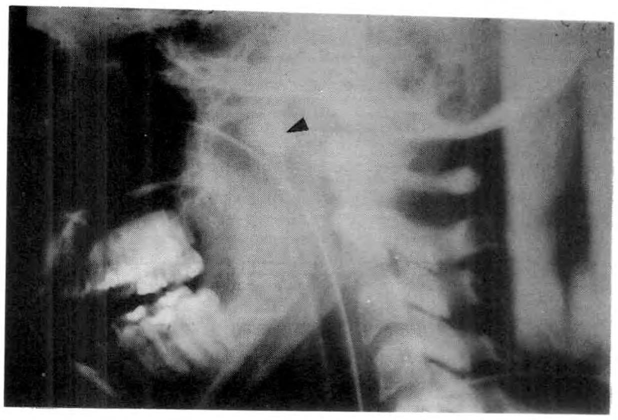

Fig. 1.

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Newcastle-upon-Tyne NE4 6BE

S.P. Whitley
I.H Shaw

Another antipollution device for the Jackson–Rees modification of Ayre's T-piece

I was interested to see the T-piece scavenging device described by Dr Kumar (*Anaesthesia* 1991; **9:** 792–3). A similar device produced by Dr J.S. Inkster and myself has been in use in Newcastle since the late 1970s. We have found it helpful to include an adjustable flow restrictor in the outflow limb of the scavenging T-connector to prevent the ventilating bag from collapsing and to allow hand ventilation. If a flow restrictor is used it is advisable to have a blow-off valve incorporated into the fresh gas flow line to prevent barotrauma. Also the system can be used quite satisfactorily with an active scavenging system.

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R.J. Bray

Life-threatening tension pneumocephalus after nitrous oxide anaesthesia

The contribution of nitrous oxide anaesthesia to the development of tension pneumocephalus is still a subject of discussion. We wish to report a case in which the continuance of nitrous oxide after dural closure quickly led to imminent brainstem herniation.

A 39-year-old, previously healthy man was referred for investigation of recurrent generalised seizures of 6 months' duration. An aneurysm of the left middle cerebral artery, and two smaller intracranial aneurysms on the right internal carotid artery, were verified by cerebral angiography. The larger, left-sided aneurysm was ligated successfully. Six months after the first operation, he was readmitted for ligation of the right-sided aneurysms. The operation was performed under general anaesthesia using thiopentone, fentanyl, pancuronium, isoflurane, nitrous oxide and moderate hypocarbia; access was gained (on the supine patient) through a right frontotemporal incision and subsequent evacuation of a large amount of CSF, after which both aneurysms were successfully ligated. Nitrous oxide and isoflurane were discontinued, coincident with tracheal extubation, on the resumption of spontaneous ventilation, immediately after skin closure. In less than 10 min, the patient became severely hypertensive (240/130 mmHg) and developed marked generalised rigidity with maximal pupillary dilation and absent light response. His lungs were hyperventiled with 100% oxygen, anaesthesia reinduced and his trachea intubated; he quickly became normotensive and the pupillary responses normal. An emergency CT scan showed a very large bifrontal pneumocephalus (Fig. 1). Because of the patient's favourable response to hyperventilation, it was deemed sufficient to continue sedation and mechanical hyperventilation on pure oxygen for 24 h postoperatively. Awakening was uncomplicated and, apart from a slight aggravation of the patient's aphasia, he was found neurologically intact. The patient was discharged home 10 days postoperatively.

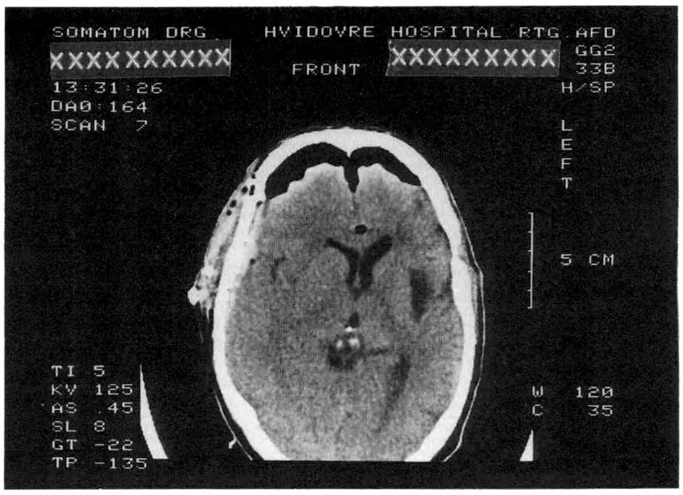

Fig. 1.

This case clearly illustrates the importance of nitrous oxide withdrawal, before or promptly at dural closure. The contention that 'N_2O anaesthesia may be safely maintained until surgery is completed, as brain reexpansion occurs after this' [1] seems unjustified.

The possibility of tension pneumocephalus should always be excluded in neurosurgical patients failing to recover from anaesthesia or showing neurological deterioration in the early postoperative phase.

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M. Sprehn
T. Faber
O. Osgaard

Reference

[1] Shapiro HM, Drummond JC. Neurosurgical anesthesia and intracranial tension. In: Miller RD, ed. *Anesthesia* 2nd edn. New York: Churchill Livingstone, 1990.

Propofol and excitatory sequelae in rats

The report of excitatory sequelae in dogs by propofol (*Anaesthesia* 1991; **46:** 797–8) has prompted us to report our findings in rats.

As part of a large programme of cardiovascular studies, 89 healthy male Wistar rats were briefly anaesthetised with isoflurane (2% in oxygen) to allow cannulation of the ventral tail artery and lateral tail vein. They were then allowed to recover consciousness (return of spontaneous movement) before being re-anaesthetised with an intravenous bolus of propofol (8 $mg.kg^{-1}$) and maintained by a continuous infusion at 30–80 $mg.kg^{-1}.h^{-1}$. All animals underwent a tracheostomy and were allowed to breathe spontaneously room air or 100% oxygen. If the initial bolus or subsequent top-up (2 $mg.kg^{-1}$) was given rapidly (< 5 s) a transient response was obtained, consisting of extensor rigidity of the forelimbs, followed by twitching of the vibrissae, blepharoclonus and finally a purposeful rubbing of the nose by the forelimbs. Slower bolus administration (5–10 s) did not produce this effect. So consistent is this finding that one of us (W.D.M.) uses it as an additional confirmatory test of the correct placement of the intravenous cannula in the rat.

These animals were all healthy and had received no drugs for premedication. We can, therefore, exclude underlying pathology or interaction with pharmacological agents (other than isoflurane). We agree with Davis and Hall that a likely explanation for this phenomenon is a direct action of propofol or its metabolites (or in our study an interaction with isoflurane).

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W.F. de Mello
E. Kirkman

Pilo-erection in anaphylactoid reaction

I was interested to read the report of Drs Rabey and James (*Anaesthesia* 1991; **46:** 897) as I had a similar case many years ago.

Immediately after the injection of thiopentone 300 mg, THA 15 mg and suxamethonium 30 mg, transient pilo-erection of both forearms occurred, sufficiently obvious to be noted and remarked upon not only by myself but also by the nursing sister who was assisting me. The subsequent series of events was similar to that reported by Drs Rabey and James and skin testing at a later date showed a response only to suxamethonium. Some years later I had another patient who had a similar severe anaphylactoid reaction to gallamine, but I do not remember pilo-erection occurring although I did not specifically look for it.

Regarding the question posed 'might pilo-erection be a useful warning ...?' my recollection is that the bronchospasm and profound hypotension occurred almost simultaneously with the 'gooseflesh' and in my opinion rather than being a warning it corroborates the diagnosis.

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C.K. Adam

Speed of onset of postoperative analgesia

In their excellent paper (*Anaesthesia* 1991; **4:** 541–4), Rice *et al.* report that, after intramuscular administration of ketorolac tromethamine or morphine, 'in no group did 50% of patients achieve a 50% reduction in pain intensity within the 60 min of the study'. Eight patients from the morphine group ($n = 28$) and nine patients from the ketorolac group ($n = 28$) had to be withdrawn from the study 'because of insufficient analgesia'. This study reflects the typical situation of patients in the early postoperative period: the main reason for this deplorable situation is the fact that, even nowadays, most analgesics are given by intramuscular injection during the early postoperative phase.

The conclusion to be drawn from the alarming results reported by Rice *et al.* is that during the immediate postoperative period, i.e. in the recovery room, analgesics should only be given by the intravenous route and intramuscular injections should be strictly avoided. Only intravenous injection ensures rapid onset of analgesia, to which every patient in severe pain has a right. Since sensitivity to pain may show wide interindividual variation, it is important to adapt opioid doses to individual requirements. A prerequisite for demand-adapted opioid titration is that the route of administration ensures rapid onset of action. Only in this way is it possible to judge the efficacy of a single bolus quickly and to decide whether an additional bolus will be required. The intravenous route is facilitated by the fact that, in the immediate postoperative period, all patients still have intravenous lines *in situ*.

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H.W. Striebel

Yet another use for the laryngeal mask

I would like to report yet another use for the laryngeal mask (LM). An 84-year-old woman with a dense right hemiplegia was in end-stage respiratory failure secondary to chronic obstructive pulmonary disease. Neurologically, there was no improvement and she remained unresponsive throughout her stay in the intensive care unit. She was successfully weaned off ventilatory support after 3 weeks of treatment. After careful discussion with her relatives, a policy decision was made not to reventilate her lungs if she deteriorated as she would have had a very poor quality of life. However, a major problem was copious secretions requiring frequent suctioning.

It is the practice of the physiotherapists in this hospital to use an oral airway in these patients in order to facilitate oropharyngeal and tracheal suction, but it was very difficult to get the suction catheter into the right position. A size 3 laryngeal mask was inserted after spraying the back of her throat with four sprays of 10% lignocaine. She tolerated the laryngeal mask without any difficulty. Suction catheters were then passed down the LM into the trachea and secretions removed easily whilst the patient was in the sitting position. She was fed enterally via a nasogastric tube, which was aspirated before physiotherapy to minimise gastric contents.

The LM was also used to facilitate oxygen delivery on the occasions when she experienced difficulty. By using a standard 15 mm connector, humidified 40% oxygen was delivered to the patient via the laryngeal mask and a T-piece breathing system. In this way, we were able to avoid reventilation. A minitracheostomy may have been more effective in helping to clear secretions. However, this is an operative procedure with definite complications. In view of the noninterventionist policy, it was decided that a minitracheostomy was probably too invasive and not justified.

Since its advent, the LM has found many different uses, mainly in the management of difficult airways. In a lecture given by its inventor, Dr A.J. Brain, he relates an occasion when he has had a laryngeal mask inserted in himself awake and found no difficulty in tolerating its presence. It was this which prompted our usage of the laryngeal mask. It was remarkable how well it was tolerated by our patient. Perhaps the laryngeal mask has a role in intensive care to aid oropharyngeal and tracheal suction without the need to resort to a minitracheostomy.

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W. LIM

Anaesthesia, 1992, Volume 47, pages 177–179

Book reviews

International anesthesiology clinics. Recovery from anaesthesia 177
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International anesthesiology clinics. Recovery from anesthesia Vol. 29, Number 2, Spring 1991

P.W. Lebowitz. Pp. xi + 121. Little, Brown, 1991. $39.00.

It seems only relatively recently that the importance of not wasting good intra-operative anaesthetic practice by inadequate postoperative care has been fully appreciated. Thus the publication of this book is to be welcomed. The first four chapters cover recovery from general anaesthesia, and the haemodynamic and respiratory changes and complications at this time. In these chapters, and indeed throughout the book, there are many practical hints which is encouraging to the reader. Such phrases a 'a little pulmonary oedema is easier to manage than a little renal failure' show that problems are put in perspective.

Further chapters look at specific drugs (benzodiazepine antagonists, opioid antagonists, neuromuscular blocking agents) and special considerations in children and at the recovery of psychological function. There is a slight bias towards North American practice with a time of 60 to 90 min quoted as the typical time after which arousal might be expected following general anaesthesia. There is an emphasis on the importance of ambulatory care throughout. It is interesting to those of us in the UK that the ASA Standards of Postanesthetic Care which are to become effective on 1 January 1992, state that pulse oximetry *shall* be employed in children during recovery from all anaesthetics during the first stage of recovery. This would certainly give us support for better equipping our recovery areas. The book is well up-to-date and includes information about the opioid antagonist, nalmefene, which has a longer duration of action than naloxone.

What I would have liked to have seen is more comprehensive coverage of the problem of postoperative pain. It is discussed in the chapter relating to paediatric anaesthesia, but I felt a chapter could have been devoted to this topic. Perhaps also a discussion about the place of high dependency units would have been useful.

It is not realistic to recommend that every anaesthetist should buy every good anaesthetic text and because I feel that this book is not likely to be read repeatedly, I would recommend anaesthetists to borrow it from the library.

G.M. Cooper

On narcotism by the inhalation of vapours. Facsimile edition with an introductory essay by Richard H. Ellis.

J. Snow. Pp. 122. Royal Society of Medicine, 1991. £20.00.

This is a work of true scholarship; historical scholarship is different from clinical science; it must be unusual for true works of the former to be achieved by practitioners of the latter, in this case anaesthesia. Dr Richard H. Ellis has again served his specialty well: he gives a careful description of the book's provenance, from three pamphlets reproduced from articles in the *Medical Gazette* in 1848, 1851 and 1852, to the publication in 1991 of this facsimile edition. He sets the scene for the book in an elegant introduction and legitimately highlights the fact that modern observation and theory is at variance with Snow's. This part of the book is an easier read than the remainder but the entire publication is pleasing.

It is an interesting work on two levels: one, that it was written at all, because up until this publication, few if any anaesthetists knew of its existence; two, because of its actual content.

Some of the accounts of Snow's experiments on small animals are, it must be admitted, almost as boring to read casually as those of the late Stewart Burns on the effects of chlorinated hydrocarbons on rats (published in *Anaesthesia* over several years) but that does not lessen either's importance. It might be very rewarding for someone to examine in detail each experiment and to check the details after conversion of the figures into modern units. Perhaps Dr Ellis has started this task already? The care with which Snow recorded, and indeed repeated, his experiments is noteworthy and should make the project relatively easy, although the chemistry is a little confusing. There are several case studies of patients and these too provide considerable insights into both the practice of anaesthesia and the general practice of medicine.

A book like this, written obviously by a single author, may reveal unintentionally something about that writer which would otherwise remain unknown. For all that might be said about the scrupulous science, the scientist himself seems to me slightly inconsistent in his attitude towards surgeons. Snow is scathing in his comments with reference to reactionary haemorrhage after ether 'probably some surgeon met with it in one or two cases'. The scorn is almost palpable. Yet two pages later he becomes typically, as one might say of anaesthetists, sycophantic: 'it would not be employed if the surgeons did not feel quite satisfied of its (chloroform inhalation) perfect safety!' A similar contradictory attitude occurs in relation to Snow's well-known teetotalism and his personal experiments with alcohol reported here. Before he recounts his own experiments designed to disprove another's theory about the exhalation of alcohol (he himself drank some) he states that oral alcohol would provide anaesthesia for surgical operations and that this use would be 'as praiseworthy as it is disgraceful when resorted to for the purpose of supposed enjoyment or to satisfy a craving which has resulted from a pernicious habit.' These words might seem a trifle bigoted to modern eyes, especially in the context of a scientific paper.

Dr Ellis believes that the publication of this volume may cause other contemporary items of value to emerge from obscurity. If this were to happen perhaps a clearer portrait of England's first anaesthetist might be drawn and we could all appreciate the tremendous accomplishments of this unusual man.

J.N. LUNN

Arrhythmia. A guide to clinical electrocardiology

E. SANDØE AND B. SIGURD. Pp. 373. Publishing Partners Verlags GmbH, Bingen, Germany, 1991. $105.00.

Written by two Danish cardiologists, this hardback book comprises 14 chapters and 373 pages. It begins with two chapters covering the fundamental principles of how the ECG is created from the physiological activity of the heart and how normal electrical activity and conduction in the heart produce the normal ECG pattern. The next two chapters give an overview of cardiac arrhythmias, including their pathophysiology, ECG appearances, aetiology, signs and symptoms, and their management. Electrophysiological catheter studies are discussed and the management section covers both pharmacological and nonpharmacological methods including antitachycardia surgery, catheter ablation of the His bundle, pacemakers and the automatic implantable cardioverter/defibrillator. The seven chapters that follow examine specific arrhythmias in more detail under subheadings of ECG diagnosis, differential diagnosis, aetiology, prognosis, investigations and management. All types of cardiac arrhythmia are covered; both common and uncommon. ECG changes associated with digitalis therapy and the ECG changes that occur with electrolyte abnormalities are given a chapter each, and the final chapter covers ECG interpretation. This chapter gives a large number of examples showing the ECG changes which occur with different cardiac and noncardiac diseases, including arterial and ventricular hypertrophy, ischaemia, pericarditis, myocarditis, pulmonary embolism, myxoedema, brain damage, neuropathic disorders and hypothermia.

The book builds from fundamental principles up to complex concepts and is very well illustrated with coloured line diagrams and a large number of demonstration ECG recordings reproduced at normal size. Each chapter is followed by a list of relevant up-to-date references and there is a comprehensive subject index at the back of the book.

In the preface the authors state that the book is directed towards a wide medical audience including general practitioners, hospital doctors, cardiologists and nurses working in the Coronary Care Unit. Anaesthetists work with ECGs every day and it is important that we recognise and interpret abnormalities and instigate appropriate treatment. It is also important that anaesthetists remain abreast of advances with the ever-increasing numbers of sophisticated pacemaker and implantable cardiovertor/defibrillator devices being produced.

The book is well laid out and easy to follow and provides a very useful reference volume for anaesthetists both in the clinical setting and in preparation for the FCAnaes examinations.

H. POWELL

The anesthetic plan: from physiologic principles to clinical strategies

S. MURAVCHICK. Pp. xiii+425. Mosby Year Book, 1991. £32.

The declared purpose of this book is to draw together the principles of applied physiology and pharmacology into the formulation of a rational anaesthetic plan. It is 'an overview of the essential interrelationships that make anesthesiology comprehensible, predictable and intellectually satisfying for intelligent and well-trained practitioners', and is designed to be a companion to the big standard texts.

It starts with two introductory chapters, one on the methods of formulating the anaesthetic plan, the second devoted to defining and measuring the anaesthetic state. The eight chapters following are each devoted to an organ system or group of systems, and these are well organised into physiological, anaesthetic and pathological considerations. Each ends with a good, clear summary. The final chapter considers risks and outcomes and the role of the anaesthetist as consultant.

The greatest hurdle in the book is the first chapter. It is densely written and almost self-defeating in its attempts to give a comprehensive overview, since the reader needs to start with a great deal of knowledge and experience to make sense of it. Once over the hurdle, however, things improve rapidly. The writing seems to settle down and becomes clear and logical, with occasional welcome flashes of dry humour. For the British reader, the American spellings and usages are at first a little strange, and, of course, some of the drug names are unfamiliar. More difficult than this, however, is the extensive use of abbreviations, such that whole pages become incomprehensible without a key. Most, but not all, abbreviations are listed in the index.

The breadth of Dr Muravchick's learning is impressive, and he is obviously a considerable teacher, carefully pursuing arguments to their logical conclusions. Inevitably perhaps, in a single author book, some aspects are better covered than others. The chapters on the anaesthetic state and various aspects of neurological function are much more satisfying than that on renal function. In each case, it is necessary to read the whole chapter to follow the argument. This is not a reference book.

There are curious imbalances. 'Riley-Day syndrome' gets virtually the same space as 'elderly patients' in a discussion of autonomic dysfunction. Mention is made of the rarest known congenital defect of platelet function (Bernard–Soulier thrombasthenic syndrome); this seems an extravagance in a book of such limited size.

The flow charts and tables are not always easy to follow, and not all repay the time taken to puzzle them out. The author says that he has referred, where possible, to widely distributed journals rather than esoteric texts. Certainly the references are copious and broadly based, predominantly American but with a pleasing number of familiar British names. They include historical items and a good number of review articles suitable for further reading. The index is, by and large, workmanlike.

The final chapter of the book attempts to draw together the threads by showing how the anaesthetic plan can be used to minimise risk. In fact, every experienced anaesthetist does precisely what is described here. He uses preoperative assessment, coupled with his knowledge of physiology, pharmacology and pathology to plan an appropriate anaesthetic sequence, which is then modified in the light of information provided by monitoring and changing surgical cricumstances. It is a useful and interesting exercise to attempt to formalise these processes and think them through in a structured fashion. For the trainee, it illustrates the close but complicated link between theory and practice, and allows him the benefit of other people's experience.

This work will not replace any of the standard texts, but is a thoughtful book and anything which encourages thought in a speciality as technical as ours deserves to be read.

A.-M. Rollin

The management of chronic pain

A.W. Diamond and S.W. Coniam. Pp. 173. Oxford University Press, 1991. £20.00.

This is a short, readable textbook of the management of choronic pain in a United Kingdom setting, which fills a gap in the present literature between comprehensive heavy tomes and specialised texts. It is ideally suited to stimulate trainee doctors in anaesthetics and other interested specialties to grasp the basic concepts of pain management and lead them on to more specific references which end each chapter. Hospital staff, general practitioners and nurses will find much in the book that is of interest. The book does not aim to present chronic pain management in depth, but gives practical background knowledge that comes from the personal clinical experience of the authors.

The realistic goals of a Pain Clinic are clearly stated and the historical development of pain clinics and associations of pain physicians is outlined. Dr Andrew Diamond, one of the co-authors, has had a formative role in the Pain Society. There are chapters on pain perception, pain assessment, back pain, myofascial pain, malignant disease, neurogenic pain, headaches and atypical pains. Treatments of these conditions are described in each section and the psychological management of pain is presented. The final chapter is a summary of protocols for pain management and comprehensively lists the points made in the preceding chapters.

The most disappointing aspects of the book were, first, the chapter on pain perception, where there was a lack of diagrams and a brief descriptive text without sufficient references to explore contemporary neuroanatomy and neurophysiology; and second, the quality of the diagrams and editing. The contribution of physiotherapists to pain management was not presented, except briefly for back pain.

If you are considering purchasing the book, look carefully at the writing on the cover. There is a twin volume on the management of acute pain of a similar size and cover. When acute pain is unrelieved, chronic pain can start. Its management requires the expertise of physicians, nurses, physiotherapists, psychologists and other supportive health care workers, working in cooperation. This book can be recommended to these categories of staff as a basic textbook for personal purchase.

A. Holdcroft

Books received

We thank the publishers for the following books, some of which may be reviewed in future issues of *Anaesthesia.*

Aids to anaesthesia: basic sciences, 3rd edn.
Edited by T.E.J. Healy, M.J. Harrison and J.A. Thornton. Pp. 272. Churchill Livingstone, 1991. £9.95.

Principles and practice of pharmacology for anaesthetists, 2nd edn.
Edited by T.N. Calvey and N.E. Williams. Pp. 522. Blackwell Scientific Publications Ltd, 1991. £49.50.

Principles of measurement and monitoring in anaesthesia and intensive care, 3rd edn.
Edited by M.K. Sykes, M.D. Vickers and C.J. Hull. Pp. 372. Blackwell Scientific Publications Ltd, 1991. £45.00.

Lecture notes on anaesthetics, 4th edn.
Edited by J.L. Lunn. Pp. 149. Blackwell Scientific Publications Ltd. 1991.

Anesthesiology review
Edited by R.J. Faust. Pp. 535. Churchill Livingstone, 1991. £27.50.

Thoracic anesthesia, 2nd edn.
Edited by J.A. Kaplan. PP. 672. Churchill Livingstone, 1991. £65.00.

Anaesthesia, 1992, Volume 47, page 180

Hazard Notice

Telectronics Reflex DDD 8222 Cardiac Pacemaker: Manufacturer's Recall HC(Hazard)(91)33

There have been some failures of the REFLEX DDD 8222 cardiac pacemaker due to over-tightening of the set-screw in the lead connector terminal posts. This results in terminal damage, particularly of the positive ventricular terminal post. The common failure mode seems to be no output subsequent to fluid ingress, although one unit has shown erratic behaviour. Any patients with such a pacemaker implanted should be referred without delay to a consultant cardiologist at a pacing centre. All stocks should be withdrawn and returned to the UK supplier.

Anaesthesia, 1992, Volume 47, pages 181–192

Association of Anaesthetists of Great Britain and Ireland

Annual Report of Council 1990–1991

1. Membership of the Association (at 30.7.91)

The total membership of the Association is 5805 (5757)

Honorary	39	(36)
Ordinary	2198	(2092)
Trainee	2094	(2117)
Corresponding	31	(33)
Overseas	767	(868)
Retired	602	(547)
Senior	11	(9)
Associate	13	(13)
Joint	50	(50)

(Last year's figures in brackets)

There were 78 resignations during the year.

Deaths

Council records with regret the death of the following members:

Biswas, D.N. (*Mandalay*), Butt, N.S. (*New Zealand*), Dalal, S.D. (*St Albans*), Donnelly, P.B. (*Co Down*), Dorrian, G. (*Dublin*), Elliott, G.N. (*Newcastle upon Tyne*), Griffin, K.D. (*York*), Hunter, A.R. (*Stockport*), Kilduff, C.J. (*Canada*), Lambie, R.S. (*France*), Lang, P.V. (*Co Donegal*), Leischman, W. (*Stirling*), Mackintosh, E. (*Leeds*), Magner, T. (*New Zealand*), McLauchlin, G.A. (*Liverpool*), Walton, W.J. (*Derby*), Warren, S.J. (*Newcastle upon Tyne*), Young, H.S.A. (*Belfast*).

2. Honorary Membership

Council recommended for election to Honorary Membership:

Dr M.M. Burrows (*Wirral*), Dr D.A. Chamberlain (*Brighton*), Professor W.W. Mapleson, (*Cardiff*), Dr J.F. Nunn (*Northwick Park*).

3. Pask Certificate of Honour

Council awarded Pask Certificates of Honour to:

Dr Ruth Hutchinson (*Zimbabwe*), Services to international anaesthesia; Mr R.A. Stratton (*London*), British Standards Institution.

4. Annual Scientific Meeting 1990

The Annual Scientific Meeting was held at the University of Manchester Institute of Science and Technology on Thursday 27 and Friday the 28 of September 1990. There were 481 registrants. An excellent scientific and social programme had been organised by Dr D.K. Whittaker, Professor T.E.J. Healey, Dr P. Morris and an active and enthusiastic Committee. The enormous success of the meeting reflected their efforts. The John Snow Lecture 'The origin of the universe and of life on earth', was delivered by Sir Bernard Lovell, Former Director, Nuffield Radio Astronomy Laboratories, Jodrell Bank.

Once again, the size of the technical exhibit exceeded all previous exhibitions, and proved a great success with both registrants and exhibitors.

The Annual Dinner was held in the Great Hall, Manchester Town Hall. Sir Cyril Smith, MBE, MP gave the toast 'The Association'.

5. Annual General Meeting 1990

The Annual General Meeting was held in the Renold Building of Manchester Institute of Science and Technology, Manchester, on the 28 September 1990. In the absence of the President Dr M.M. Burrows, the Honorary Treasurer, Dr W.R. MacRae invested Dr P.J.F. Baskett with the President's medallion. Dr Baskett presided over the meeting attended by 219 members.

The Certificate of Honorary Membership was presented to Dr C. Parsloe. Dr Parsloe was elected to Honorary Membership at the 1989 meeting but had been unable to attend. Honorary Membership was conferred upon Dr T.B. Boulton (citation, Dr R.S. Atkinson), Dr R.J. Maxwell (citation, Dr J.N. Lunn), Professor O. Mayrhofer (citation, Dr J.S.M. Zorab), Professor H. Ruben (citation, Dr P.J.F. Baskett).

Pask Certificates of Honour were awarded to Dr M.J. Mowbray, Nottingham, Dr Wendy Scott, Milton Keynes, Mr R. Sugg, BAREMA and Dr. R.S. Vaughan, Cardiff. Council awarded a Pask Certificate of Honour to Dr. L. Kaufman who was unable to attend. (Dr Kaufman received his certificate prior to a meeting of Council on 1 February 1991).

Minutes of the Meeting have been circulated to members.

6. Linkman Conference 1990

The 15th Annual Conference of Linkmen was held in the Renold Building, University of Manchester Institute of Science and Technology, Manchester on Wednesday 26 September 1990. The Honorary Treasurer, Dr W.R. MacRae was in the chair and 236 Linkmen attended. The principal topics addressed included anaphylactic reactions associated with anaesthesia (Dr W.S. Nimmo), the Department of Health working party on dental anaesthesia (Dr D.A. Zideman), safety and monitoring for endoscopy under sedation (Dr J.E. Charlton), the conduct of independent practice (Dr R.M. Weller) and workload for consultant anaesthetists (Dr W.R. MacRae).

A full report of the Conference was published in *Anaesthesia* (1991; **46:** 606–11).

7. Postgraduate Study Day 1990

This meeting, organised jointly with the College of Anaesthetists, was held on Saturday 13 October 1991 at the Royal College of Surgeons of England, London. The format was similar to that found to be successful in previous years and over 300 registrants were able to attend six lectures of their choice from a total of eighteen lectures delivered.

8. Winter Scientific Meeting 1990

The fourth annual Winter Scientific Meeting of the Association was held at the Queen Elizabeth II Conference Centre, London, on 18-19 January 1991, with an excellent scientific programme organised by Dr J.A.W. Wildsmith and his colleagues. There were 218 participants who enjoyed the superb facilities offered by the new venue for Association meetings. In addition there was a vigorous trade exhibition.

The BOC Health Care Lecture was delivered by Professor W. Runciman, Professor and Head of Department of Anaesthesia and Intensive Care, Royal Adelaide Hospital, Adelaide, Australia. The title of Professor Runciman's address was 'Balancing cost, benefit and risk—the major challenge of the future'. The Association is grateful to BOC Health Care for their continuing support for this prestigious annual guest lecture.

The Winter Dinner was held at the Waldorf Hotel, London, on Friday the 19 January, 1991. The toast 'The Association' was given by Mr Charles Barton QC, Barrister at Law. Other distinguished guests included Major General P. Beale, Professor K.C. Calman, Mr J. Chawner, Professor G.D. Chisholm, Sir Cecil Clothier KCB QC, Sir Anthony Grabham, Dr D. Moriarty, Surgeon Rear Admiral D. Lammiman LVO, Sir Gordon Robson, Professor P.D. Wall FRS, Mr S. Simmons and Mr A.P.J. Ross.

9. Anaesthetists in Training Annual Scientific Meeting 1991

This meeting, hosted by the Nuffield Department of Anaesthesia, Oxford, was held at the John Radcliffe Infirmary, Oxford on 3–5 April, 1991. There was a record attendance of over 350 registrants which attested to the superb quality of the comprehensive scientific and social programme organised by the Chairman, Dr P. Foëx, and his Committee. The scientific programme included sessions devoted to respiratory monitoring and support, pain control, craniofacial surgery, audit, measurements in anaesthesia, the problems of anaesthesia in the patient with cardiac disease and, most importantly, how to succeed in anaesthesia.

The Pinkerton Lecture, entitled 'From Black Gas to Propofol' was delivered by Dr. T.B. Boulton, OBE, Past President of the Association and Honorary Archivist. Prior to the lecture, a citation to Dr Boulton was delivered by Dr Wendy Scott. It should be noted that Dr Boulton was accorded a prolonged standing ovation by his audience in appreciation of his presentation.

The President's Medal for the Anaesthetists in Training Annual Prize Competition was awarded to Dr C. Frerk, Manchester, for his paper on the assessment of the potentially difficult intubation. A second prize was awarded to Dr P. Wright, Belfast.

The Annual Dinner was held in the magnificent setting of the Hall of Christ Church. The toast to the guests was proposed by the Chairman of the Anaesthetists in Training, Dr Elizabeth M. Spencer. Dr E.B. Lewis replied on behalf of the guests.

10. Other Meetings

8th European Congress of Anaesthesiology. The 8th European Congress of Anaesthesiology and Intensive Therapy, was held in the Palace of Science and Culture, Warsaw, Poland, on 9–15 September, 1990. At the General Assembly of the European Section, World Federation of Societies of Anaesthesiology (WFSA) presided over by Dr P.J.F. Baskett, the Immediate Past Honorary Secretary of the Association, Dr W.L.M. Baird, was elected Honorary Secretary of the European Regional Section of the WFSA.

11. Council

Council and the Advisory Committee have met throughout the year. Attendance of Officers and Elected members of Council and Advisory Committee is detailed in Appendix A, together with membership of sub-committees, Association working parties and Association representatives to other bodies.

Dr M.M. Burrows, Professor M. Rosen CBE and Professor M.D. Vickers, all Past Presidents of the Association, retire after many years of continuous and devoted service to the Association in various capacities. The debt of gratitude owed by the Association to these individuals is inestimable.

Air Commodore C.A.B. McLaren and Dr P. Morris retire on completion of two years as Vice Presidents. Council is grateful for their advice and efforts on behalf of the Association.

Drs J.E. Charlton, Margaret L. Heath and S.M. Lyons, Elected members of Council, retire after their four year term of office. All have taken an active role in the Association and Council thanks them for their respective contributions. Dr J.A.W. Wildsmith retires as Chairman of the Education and Research Committee. Council is grateful to Dr Wildsmith for the many contributions he has made to the Association in various capacities.

Council is delighted to record its congratulations to Dr T.B. Boulton, Past President and Honorary Archivist, on the richly-deserved honour of an OBE. More recently, the President, on behalf of Council and the Association, wrote to congratulate Professor Sir Keith Sykes, Vice President, upon the award of his knighthood. Members will have the opportunity to congratulate Sir Keith personally at the Diamond Jubilee Scientific Meeting when he will deliver the BOC Health Care Lecture.

The secretariat, under Miss Ann Muir, Administrative Secretary, has continued to ensure the smooth running of the Association's many activities. The Honorary Secretary is particularly grateful to Mrs Sally Jenner who has exceeded every reasonable demand and most unreasonable demands made upon her administrative skills. Mrs Lyn Frimpong has admirably fulfilled the duties of BOC Educational Co-ordinator during Mrs Lesley Ogg's period of leave. The continued assistance of Miss Jacqui Wallace and Mrs Betty Tyler is warmly acknowledged.

Council is deeply appreciative of the continued help and advice on financial and legal matters given by Mr Ernest Warburton. Mr Warburton has been ably assisted by Ms Pat Plant, Financial Assistant.

Anaesthesia continues to go from strength to strength under the Editorship of Dr M. Morgan. Council welcomes Dr M. Harmer, Cardiff, as an Assistant Editor.

Council and members of the joint Association and College of Anaesthetists working party circulated members with additional advice on Consultant Workload. This included several examples to aid the formulation of job plans.

Council has offered a strong and positive response to the report of the Department of Health working party on dental anaesthesia chaired by Professor D. Poswillo.

Officers of the Association held discussions with representatives of the Department of Health concerning the new model Consent Form. As a consequence, advice was offered to members with regard to the form. Further work is being undertaken to provide patient information literature about all aspects of anaesthesia which will aid obtaining informed consent.

The Association has endorsed the guidelines for fees in private practice published by the British Medical Association. Dr W.R. MacRae, Honorary Treasurer, and Dr W.L.M. Baird, Immediate Past Honorary Secretary, have met representatives of BUPA throughout the year. A full report of these discussions was sent to Linkmen in the last Linkman letter. It is profoundly disappointing to report that BUPA have made little effort to achieve constructive progress. Fuller details are given in the report of the Private Practice Committee.

Council has agreed to form working parties to study the following topics in the forthcoming year.

(i) Departmental accommodation and secretarial assistance (Chairman: Dr W.L.M. Baird)
(ii) Workload for non-consultant career grades (Chairman: Dr P. Morris)
(iii) Hepatitis and HIV (Chairman: Dr J.F. Searle)

Council agreed to offer aid to the College of Anaesthetists to enable them to purchase a property should a suitable home for the College become available. A suitable property, number 8 Bedford Square, became available, and to complete purchase Council of the

College indicated that it wished to accept the offer of a loan from the Association.

The Association's initial offer was an interest-free loan of £500 000, which would be repaid over a number of years subject to certain conditions being met. Advisory Committee, on behalf of Council, felt it would be advantageous to both the Association and the College if the Association's loan was expressed as a percentage of the equity. Particularly, this would avoid the need for repayments by the College, and would be an elegant fulfilment of one of the original aims of the Association for the foundation of an independent body for anaesthesia. The College of Anaesthetist did not agree to this and has accepted the Association's original offer of an interest-free loan. After further discussion, Advisory, on behalf of Council, agreed to the College's proposal that they would pay interest on half the amount of the loan.

The Association welcomes the College of Anaesthetists as its neighbour and looks forward to mutual co-operation to develop both organisations as strong and powerful advocates of our specialty.

12. Group of Anaesthetists in Training (Chairman: Dr Elizabeth M. Spencer)

The Committee met four times during the year. There have been three resignations from the Committee: Dr P.J. Heath, Chairman, Dr Susan M. Anderson and Dr I. McMenemin. All have worked hard on behalf of trainees, and special mention must be made of the contribution of Peter Heath during his time as Chairman. We are happy to welcome Dr A.P.L. Goodwin, Dr A.B. Lumb and Dr Rebecca J. Sparling to the Committee.

The Annual General Meeting was held during the Annual Scientific Meeting at the John Radcliffe Infirmary, Oxford. Members voted to abandon the term 'junior' in favour of 'trainee'. The Committee feels this is a major advance, and is in recognition of a group of highly trained professionals. This change has the full support of Council of the Association and the College of Anaesthetists. The Committee has decided, for the present, that the trainee committee should be known as the Group of Anaesthetists in Training (GAT).

The *Handbook for Trainee Anaesthetists* has now been published and was available at the Oxford meeting. All trainee members will receive a copy upon joining. Also available at Oxford was the second edition of the Career Guide.

A consignment of textbooks was sent to Poland in September 1990, and a second batch will be sent to Romania shortly.

The number of Trainee Linkmen continues to increase. The Annual Linkman Seminar was held in October 1990 on the topic of audit. Members of the Committee continue to represent trainees on the Committees and working parties of the Association, and on College and other anaesthesia-related bodies. The names and addresses of members of the Group of Anaesthetists in Training Committee are published monthly in *Anaesthesia News*, and trainee members are encouraged strongly to contact members of the Committee or their Linkman for any information they may require.

13. Association of Anaesthetists Standing Committee, Republic of Ireland

A full constitution has been agreed by Council for the Irish Standing Committee. This was presented to an Open Meeting of members in the Republic of Ireland held on 9 March 1991 in Dublin. This meeting was attended by Dr W.R. MacRae, Honorary Treasurer, Dr J.E. Charlton, Honorary Secretary and Dr W.L.M. Baird, Immediate Past Honorary Secretary.

A preliminary report of a working party on the problem of small peripheral anaesthetic units was considered in detail and areas of particular difficulty were identified. It was recognised that a solution to this problem would be difficult, but constructive suggestions were considered. The Association is grateful to Dr Kate O'Loughlin and members of her Committee for their hard work.

The Committee has continued to meet with representatives of the Voluntary Health Insurance Board (VHI) and in January 1991 held a special Open Meeting to discuss the latest proposals for anaesthetic fees. There was considerable opposition to a proposal from the VHI that anaesthetists in the Republic of Ireland sign an undertaking not to charge fees at a rate higher than the proposed schedule. The considerable efforts of Dr A. Synott to provide information concerning costs and fees for anaesthesia were of inestimable value.

The Association is grateful to the Officers of the Irish Standing Committee for their continued hard work.

14. Linkmen Organisation

Dr R.S. Vaughan, Assistant Honorary Treasurer and Linkman Co-ordinator has continued to keep Linkmen informed of the activities of the Association through Linkman letters. Many of the matters considered by Council this year have been of fundamental importance to our specialty and Council is grateful to Linkmen for providing clear views from the membership on these topics. The help and support of the Linkmen is much appreciated by the Association's Officers.

15. Seminars and Workshops at 9 Bedford Square

The active programme of seminars has continued throughout the year. Their popularity is manifest by the fact that new and repeat seminars were inevitably over-subscribed.

Council is grateful to Professor A.R. Aitkenhead and those members who have helped him organise the seminar programme in conjunction with the BOC Educational Co-ordinator Mrs Lesley Ogg. In particular Council wishes to thank Mrs Lynn Frimpong for carrying out the duties of the BOC Educational Co-ordinator so well during Mrs Ogg's recent leave.

16. Editorial Board (Chairman: Dr P.J.F. Baskett, President)

The Board met on two occasions in 1990–91. Dr J.N. Lunn resigned his position as Editor of *Anaesthesia*, a post he had held for 10 years, and ended a 17 year association with the journal. The Board and the Association are grateful to him for his unstinting efforts during this time. Dr M. Morgan of London was appointed as his successor. Dr L. Kaufman, who compiled the Anaesthetic Literature section of the journal for 25 years, has retired from his post. He was presented with a Pask Certificate of Honour by the President before the February meeting of the Council in recognition of his considerable efforts during this time. Due to growth of electronic retrieval systems this section of the journal has now been discontinued. Dr Cyril F. Scurr left the Board on which he has served since 1983, and the Board is grateful for his contributions.

The Board has been strengthened by the appointment of Dr M. Harmer, Cardiff, as an Assistant Editor. Miss Janet Springer of Southampton has replaced Miss Jacqui Welch as one of the librarians, and an additional librarian, Mrs Anne Graham of Nottingham, has been appointed.

The publishers, Academic Press, pointed out that early in 1991, the publishers of *Today's Anaesthetist*, who are about to launch a new title, *Today's European Anaesthetist*, put out erroneous circulation figures of *Anaesthesia* to European countries. This was considered unethical and condemned.

17. Anaesthesia News (Dr J.N. Horton)

Anaesthesia News has been produced monthly in the new A4 format. In accordance with a decision of the Management Board taken in June 1990, a readership survey was carried out in December. This indicated overwhelming support for the new format. In addition, there were many helpful suggestions for features which will be taken up in future issues.

The features 'News and Notices' and 'National and Local Events' have been combined into a single calendar. Details of specialist societies will no longer be published in each issue which will permit more room for other features. Articles expressing points of view, items of topical interest and other material, particularly pictures, are always welcome.

18. Anaesthesia Management News

This Association publication is edited by Professor M.D. Vickers assisted by Dr Lauren Allan. It is circulated to managers within the health service and highlights anaesthetic matters with implications for management. Linkmen are asked to ensure that their Unit Managers receive a copy and have the opportunity to discuss the contents. Council has considered the future of this publication and has asked for feedback concerning its value as a method of informing management.

19. Education and Research Committee (Chairman: Dr J.A.W. Wildsmith)

The Committee met three times during the year and continued its work of supervising the Association's programme of postgraduate meetings and seminars, as well as adjudicating on applications for research and travel grants.

Association Research Fellowship

The Committee is pleased to report that 19 high quality applications were received for the Association Research fellowship. After consideration of expert reports and interview of the main candidates, the Fellowship was awarded to Dr Jane Peutrell, (*Bristol*).

Research Grants

Council approved the following applications on the recommendation of the Education and Research Committee: Dr P.M. Hopkin and Dr F.R. Ellis, (*Leeds*) £5000 (part support) to study the site and mechanism of abnormal calcium homoeostasis in malignant hyperthermia. Dr M.P. Coplans and Professor I. Curson (*London*) £600 to study a survey of all deaths associated with dentistry: the second decennium (1980–1989). Dr D.G. Bogod and Dr Alison Campbell (*Nottingham*) £5000 to study long term backache following epidural anaesthesia for childbirth.

Two other requests were reviewed but not recommended to Council.

Travel Grants

Council approved the following applications for travel grants: Dr K.J. Power (*Southampton*) £500 in support of a visit to trauma centres in the USA.

Members considering an application for a travel grant may like to note that the maximum sum that can be awarded has been increased to £750.

Baxter Healthcare Travelling Fellowship, 1990

This Fellowship was awarded to Dr A.J. Lee (*Edinburgh*) to visit Presbyterian University Hospital, Pittsburgh to study changes in blood coagulation associated with intravenous fluids.

Council is grateful to Baxter Healthcare for their continuing support for this Fellowship which is a valuable contribution to the speciality. Council encourages more members to apply.

Undergraduate Prize Essay, 1991

Three prizes were awarded in the clinical section. The first prize was awarded to Mr R.A. Patey (*Guy's Hospital*) for his essay entitled 'The laryngeal mask airway—a review'. Second prize was awarded to Mr J.S. Luty (*Leeds*) for an essay entitled 'Awareness under anaesthesia—techniques for monitoring awareness under general anaesthesia', and a third prize was awarded to Mr W.R.A. Smith (*University of Leeds*) for an essay on 'Chronic exposure to trace concentrations of anaesthetic gases'.

The Association is pleased to acknowledge its debt of gratitude to the experts who have provided advice in reviewing applications throughout the year.

Scientific Meetings

The Association held four major meetings during the year. The Annual Scientific Meeting was held in Manchester, and for the last time for at least five years this was in the traditional venue of a University campus. The continued success of the meeting has led the Education and Research Committee to believe that it has outgrown many such facilities and, for the future, the meeting will be held in purpose-built conference accommodation. The London-based Winter Scientific Meeting was, for the first time, held in such a facility, the Queen Elizabeth II Conference Centre, Westminster. The attendance was less than anticipated, but was probably influenced by the Gulf war. Next year's meeting will be at the same site and will celebrate this Association's Diamond Jubilee.

The Annual Meeting for Anaesthetists in Training continues to be very popular and successful. The fourth major meeting, the Postgraduate Study Day, is held in association with the College of Anaesthetists, and has been suffering from falling attendances. However, last year's programme reversed this trend, but nonetheless, there is to be a reappraisal of its style and timing after this year's meeting.

The final component of the postgraduate programme are the Seminars at 9 Bedford Square, which are reported in the previous section of this report.

Future Meetings

The calendar of future Association meetings is detailed in Appendix B.

20. Safety Committee (Chairman: Professor P. Hutton)

The Safety Committee has met twice during the year. Following the publication of the Association documents 'Checklist for Anaesthetic Machines' and 'Anaphylactic Reactions Associated with Anaesthesia', plasticised sheets have been prepared for use in operating theatres. These have been distributed to Linkmen and further copies are available from the Association offices. The Department of Health have recommended the Checklist in their Safety Action Bulletin (91)10 published in March 1991.

Discussion continued concerning the use of 22 mm breathing system connections and many letters on this subject were received from members. The conclusions were brought to the attention of the Department of Health who published SAB (91)11 published in March 1991 entitled 'Anaesthetic and Respiratory Equipment: Supplementary Advice to that Contained in SAB (89)78 on the use of 22 mm Breathing System Connections'. It is hoped that the situation with respect to the new fittings is now clear.

Dr D. Short, Chairman of HCC/45 drew the attention of the Safety Committee to the dangers of printing preformed tracheal tubes with a range of ages. This implied that a certain size of tube was correct for a certain age of patient which is clearly a potential hazard. Following discussion and liaison with the manufacturers all mention of age has now been removed from the tubes and a brief report on the situation was published in *Anaesthesia News*.

The Committee has continued to press the Secretaries of State at the Departments of Health and Trade and Industry for support for representatives to participate in the formulation of the international and European standards concerning anaesthesia.

Representatives of the Department of Health drew the Committee's attention to problems which had been experienced with the insufflation of oxygen and an editorial drawing attention to these hazards is being prepared for *Anaesthesia*.

The Safety Committee wrote to the Association of British Pharmaceutical Industries (ABPI) expressing concern about some instances where drugs used in anaesthetic practice had been withdrawn without prior consultation with representatives of the specialty. To improve lines of communication the ABPI was invited to send a representative to sit on the Safety Committee but disappointingly they felt that this would be of little value. It was agreed that the Association should not pursue the ABPI on this matter but seek to establish closer links with pharmaceutical companies whose products were of relevance to anaesthesia.

Representatives of the Safety Committee are currently liaising with representatives of the Department of Health on the efficiency of systems for reporting defects which arise in anaesthetically related equipment.

The Health and Safety Commissons' Advisory Committee on Toxic Substances is currently considering nitrous oxide, halothane, enflurane and isoflurane and progress on this is being monitored by the Safety Committee who send a representative to the relevant meetings.

21. Finance Committee (Chairman: Dr P.J.F. Baskett, President)

The Finance Committee has met twice during the year. The funds of the Association remain satisfactory, but during the year the managed investment arrangement introduced several years ago with a leading stockbroker was discontinued because of a poor overall performance.

The Finance Committee agreed to recommend to Council that substantial support be offered to the College of Anaesthetists were it to seek independent premises. Such support would take the form of an interest-free loan of up to £0.5 M repayable over a number of years.

The audited accounts of the Association have been circulated to members. The Committee is most grateful for the work of Mr Ernest Warburton, Financial Adviser, and Ms Pat Plant, Financial Assistant.

22. International Relations Committee (Chairman: Dr S.M. Lyons)

The Committee has continued its work during the year fostering its interest in the Developing World and seeking to establish links with Eastern Europe. There are obvious financial implications in extending the activities of the Committee and different methods of funding, apart from a direct drain on funds of the Association, were considered. It was decided to approach National, Regional and Specialist Societies in the British Isles to ascertain if they would be prepared to assist with the funding of lecturers to overseas Refresher Courses, and to help in the nomination of the lecturer to such a course. This has met with a gratifying response. During the past year the Society of Anaesthetists of the South Western Region (SASWR), together with the Association provided funds to allow Dr C. Monk (*Bristol*) to take part in the Refresher Course held in Moscow in April 1991. This was a very successful course and Dr Monk was an excellent representative of the Association and the SASWR.

A similar approach has been made to the Scottish Society of Anaesthetists and they have agreed, together with the Association, to fund a lecturer to attend the Refresher Course in Moshi, Tanzania in August 1991. Dr I. Levack (*Aberdeen*) has been nominated as the lecturer.

The Committee are most appreciative of the generosity of these societies and intend to proceed with this initiative. In conjunction with other societies, it is hoped that funding can be provided for two lectures per annum to overseas Refresher Courses. This will widen the scope of the Association's work abroad and, in turn, directly involve a greater number of members in this endeavour.

The Committee has maintained contact with the British Council and the Overseas Development Association in areas of interest overseas. Dr Coates has recently completed two years with the Overseas Development Association in Fiji, and a successor, Dr Puttick, has been found for this work. The British Council were seeking a Paediatric Cardiac Anaesthetist to visit Thailand for one month. Dr Young from Harefield has volunteered for the post.

The Association has been involved in a five year programme of sending post-Fellowship registrars to the Children's Hospital in Katmandu, Nepal. This work is now finished as the hospital is self-sufficient. The contribution of the young UK anaesthetists will be missed, but the hospital has expressed its extreme gratitude to the Association for its help.

The Committee looked at methods of sending books and journals overseas to help departments who need them. Transportation costs are high, but Operation Christmas Child have offered to help with transport and it is hoped to take up this offer in the near future.

23. Private Practice Committee: (Chairman: Dr R.M. Weller)

The Committee has met formally on three occasions. However, a great deal of work has gone on between these meetings, and their relative infrequency is no indication of a slackening of the efforts that this committee makes on behalf of members. Council approved the recommendation of the Private Practice Committee that the Association adopt the British Medical Association (BMA) document 'Private Consultant Work: BMA Guidelines 1990' for advice about the level of fees in the independent sector. Though publication of this document was delayed until December 1990, the Committee felt that the BMA had rectified many of the striking anomalies of their 1989 document. It was felt that the BMA guidelines were reasonable and fair to all concerned and that it was not necessary for the Association to produce its own guidelines in 1990–1991. A cost-of-living rise of 10.5% has been introduced, effective from April 1991, which is in line with the pay award recommendations of the Doctors and Dentists Review Body Report.

With one major exception, the Provident Societies and insurance companies seem prepared to cover fees up to the level recommended by the Association and the BMA in their guidelines.

The major exception is BUPA who have failed to provide for full reimbursement for many procedures. Members have been advised repeatedly to follow the BMA guidelines, and to ask patients to cover any shortfall, as regrettably, this appears the only way to address this problem. The importance of informing patients beforehand that a shortfall may occur is stressed.

Slight progress was made during the autumn of 1990, when BUPA agreed to consider every 'Minor' as a 'Minor 5', with benefit of £70 available for the anaesthetic fee. At a meeting in January 1990, representatives of BUPA agreed, but then failed to implement, an increase in the level of benefit available for certain cardiothoracic procedures. This agreed increase was delayed until 1 July 1991 when BUPA introduced revised levels of benefit for anaesthesia. None of the revised levels are in line with the cost-of-living salary increases awarded by the Review Body.

The Committee has considered a number of contentious areas, and some of these will be presented to the Linkman Conference. These include the possibility of charging fees for various methods of postoperative analgesia, such as PCA, infusions and epidural analgesia, and fees for the management of chronic pain. Additionally, the level of fees for procedures requiring anaesthetic 'standby' and 'sedation' were considered. Inconsistencies, errors and omissions in the 1990 BMA guidelines have been collected to aid the BMA in their revision prior to a new edition.

The Committee is aware that increasing numbers of members are following the BMA guidelines and urges others to follow suit. Both undercharging and overcharging weaken the position of the anaesthetist. Our aim has always been to recommend fees that are fair and reasonable to our patients and for our members.

24. Museum, Library and Archives Committee (Chairman: Dr T.B. Boulton)

The Committee has met on three occasions during the past year, under the Chairmanship of Dr Boulton, the Honorary Archivist. Its responsibilities include the supervision of the collections of historical equipment, books and memorabilia, the maintenance of the archives of the Association, and the supply of information to enquirers. Dr Audrey Eccles (ICI Archivist/Librarian) continues her invaluable work in co-ordinating all these areas of activity.

The BOC Museum (Honorary Curator, Dr D.J. Wilkinson) has continued its policy of an annual change of exhibit. The 'Painless tooth-pulling' exhibit was lent to the Monica Britton Memorial Hall of Medical History at Frenchay Hospital, Bristol, and replaced by an exhibition of ventilators 'Let the machine breathe for you'. A new slide set was produced in conjunction with this exhibition. Close liaison is maintained with the Science Museum, South Kensington, through Dr Ghislaine Lawrence (Honorary Curatorial Adviser). A joint meeting was held in August at the Science Museum for curators of anaesthetic apparatus in hospital collections, to offer advice and help in improving the standards of physical care and documentation of such collections. Some larger items of equipment have been passed to the Science Museum for safe-keeping because of the lack of adequate storage facilities available to the Association.

The BJA Library (Honorary Librarian, Dr I. McLellan) has maintained a policy of modest expansion and has become a very valuable resource. A unique feature is the collection of audio-visual material, the majority of which has been copied on videotape.

The historical resources of the Association have been publicised by Dr Eccles in a paper presented to the Society of Welsh Anaesthetists at Swansea and in two recent articles in *Anaesthesia News*.

The historical holdings continue to grow by important donations, and by the purchase of suitable items, especially library books, and computer inventories have been completed of most groups of material. The Committee has begun work on publications and exhibits designed to celebrate the Diamond Jubilee of the Foundation of the Association in 1932.

25. 1992 Diamond Jubilee Planning Committee (Chairman: Dr P.J.F. Baskett)

The Committee has met on several occasions to plan events and commemorative items to celebrate the 60th anniversary of the founding of the Association. The Committee is delighted that Dr T.B. Boulton, the Honorary Archivist, has agreed to write a history of the Association. Work on this project is well advanced and it is hoped to publish the completed work early next year.

A special meeting has been planned in place of the normal Winter Scientific Meeting. The meeting will take place on the 10th and 11th of January 1992 at the Queen Elizabeth II Conference Centre in London and there will be an Opening Ceremony by our Patron, HRH The Princess Margaret, Countess of Snowdon. The programme features presentations on the development of aspects of anaesthesia throughout the six decades of the Association's existence. A dinner will be held in the Connaught Rooms.

26. Anaesthetics SubCommittee, CCSC (Chairman: Dr S.M. Lyons)

The Committee met on two occasions and the Chairman has reported the activities of the Committee to the Council of the Association and to the Central Consultants and Specialists Committee (CCSC) of the British Medical Association (BMA).

The revised edition of 'Private Consultant Work—BMA Guidelines' was issued at the end of 1990. This edition had much more direct anaesthetic input than the previous edition, and the Committee was grateful to the Private Practice Committee of the Association for advice. This edition is now being widely used to provide guidelines for anaesthetic fees, and these will be reviewed, updated and anomalies eliminated as the need arises.

The Committee considered Consultant Job Plans and endorsed the guidance given by the Association. This will be kept under close scrutiny as experience unfolds.

The funding of dental anaesthesia has always been a contentious area. The Committee welcomed the publication of the Poswillo Report which may give the opportunity to improve patient care, and permit realistic remuneration for those who take part in this area of practice. This will depend largely on adequate funding to permit implementation of the major recommendations. The Committee submitted comments about the details of the report.

The application and utilisation of Staff Grade posts in anaesthesia was reviewed from the viewpoint of type of job description and the qualification demanded of applicants. The Committee endorsed the guidelines as agreed for these posts and will continue to monitor developments.

The potential problems of Terms and Conditions of Service in Trust Hospitals, and the possibility that doctors may find it more difficult to attend local and national committees was discussed. This was highlighted and will be kept under review. There are also some problems that patients are being referred for day case surgery who do not fit agreed criteria This may reflect the pressures created by bed closures. The Committee was strongly of the opinion that patient safety was paramount.

27. Specialist Societies of Anaesthesia

The Annual meeting between Officers and Representatives of the Specialist Societies was held on 16 November 1990.

Arrangements have been made for specialist societies to be responsible for a session at the Winter Scientific Meeting. The purpose of this session is to promote awareness of recent developments in specialist areas that would benefit colleagues in a broader field. The first presentation was by the Association of Paediatric Anaesthetists at the 1991 meeting. There will not be a specialist society presentation in 1992 as there will be a special meeting to celebrate the Diamond Jubilee of the Association. The Association of Cardiothoracic Anaesthetists will contribute to the 1993 meeting.

The proposal that meetings of specialist societies be co-ordinated with major meetings had been discussed by the specialist societies. It was felt that this would be difficult to arrange as most societies had a limited number of meetings at fixed times of the year. Problems were anticipated with covering service commitments if juxtaposition of meetings led to prolonged absences of large numbers of people.

Representatives of the specialist societies presented their activities during the year and those proposed for the future. Problems related to practice in the independent sector and to the provision of study leave were of particular concern to many present.

28. Working Parties

Assistance for Anaesthetists (Chairman: Dr P.J.F. Baskett, President). The working party has concentrated mainly on issues surrounding the training of assistants. At the time of writing, the National Council for Vocational Qualifications is considering the submission for a Level 3 National Vocational Qualification (NVQ) to which the working party has made substantial contributions. It is hoped that the subsequent Standard will ensure the level of skill and understanding required by non-medical operating department workers. Although the supporting documentation and training of assessors is not yet complete, sufficient progress has been made for many Operating Department Assistant (ODA) training schools to feel confident that they can direct training towards the new qualification as soon as it is approved.

Qualifications above and below this level are planned also. The Level 2 NVQ is likely to be a variant of the Health Care Assistant and will provide some formal training and a qualification for Operating Department Orderlies and Auxiliary Nurses. Although it could provide a preparation for further training, there has been unqualified acceptance of the Association's view that this level could not provide anything other than supplementary help to the skilled members of the anaesthetic team.

The Level 4 NVQ will give scope for career advancement within clinical specialisation (surgical or anaesthetic), management and teaching.

It remains to be seen whether adequate resources for implementation of these changes will be made available in all places: there is evidence of considerable variation in the support being given to ODA training schools and we hope to influence matters favourably.

The examination for the City and Guilds 752 certificate, (the current ODA qualification), will remain available as long as required. It must be stressed that this is still appropriate and valid although the refinement and redirection of training that will be needed to effect performance assessment within the workplace should produce benefits, both for trainees and for existing ODAs, who will become more involved in training. It also seems likely that the new qualification will be attractive to nursing staff and may increase the two-way exchange of training expertise.

The relative dearth of good courses for nurses wishing to specialise in anaesthetic related work has continued. The English National Board's six month course (ENB 182) is almost extinct and the ENB 183 course which seeks to combine theatre, anaesthetic and recovery nursing may not be universally satisfactory because of the lack of central guidance on content, the variable weight attached to anaesthetic advice by different centres and the reduced overall length of the training. A variety of short training courses have also been initiated in other countries.

Anaesthetists should appraise carefully the level of skill and understanding attained by nurses aspiring to work with them. They should not accept inadequately trained assistance either for themselves or for their trainees, and help provided in isolated areas such as obstetric units must be assessed particularly carefully. Members are encouraged to seek the assistance of the Association where difficulties cannot be resolved satisfactorily. The Chairman and Officers of the United Kingdom Central Council for Nursing, Midwifery and Health Visiting have been made aware of the Association's concerns at a helpful informal meeting. In addition, the Association's response to their 'Post-registration Education and Practice' report highlighted the neglect of training in specialised areas.

The retention of trained ODAs within the National Health Service has continued to make progress as a result of the improved pay and regrading. We continue to press for a statutory registration scheme, as recommended in the Bevan Report, since this would have significant advantages for both ODAs and their employers.

As a response to concerns expressed by members involved in local training programmes for anaesthetists' assistants, a communication circle has been set up to allow exchange of information, experience and solutions to problems within this field. Anyone wishing to join should contact Dr Margaret Heath via the Association offices.

Services for Chronic Pain Relief (Chairman: Dr J.E. Charlton, Honorary Secretary). The suggestions for increased training in pain relief made in the interim report of the working party published last year have now been included in revised editions of the College of Anaesthetists' guidance on Basic Specialist Training. In view of the increased interest in pain relief, the working party will meet again in the near future.

High Dependency Units (Chairman: Dr J.A.W. Wildsmith). The working party published its report 'The High Dependency Unit—acute care in the future' in Spring 1991.

Workload for Consultant Anaesthetists (Chairman: Dr M.M. Burrows, Immediate Past President). This joint working party with the College of Anaesthetists and representatives of the CCSC published its report in July 1990. It was apparent that more detailed advice was necessary and the joint working party issued further advice in January 1991. This working party will meet again if circumstances warrant it.

Role of the Anaesthetist in the Emergency Service (Chairman: Dr P.J.F. Baskett, President). This multidisciplinary working party has met on five occasions and the report of the working party was published in August.

The document gives guidance concerning the role of the anaesthetist in the Accident and Emergency department in providing both anaesthetic and resuscitation services, and their commitment to training medical, nursing and ambulance paramedical staff. A section of the document is concerned with pre-hospital care and involvement in major disasters.

Media Liaison (Chairman: Dr P.J.F. Baskett, President). This working party has met twice. Matters discussed include responding to media enquiries, promoting anaesthesia and, in particular, the work and publications of the Association. Draft patient information leaflets are being prepared to aid patients and house staff understand more about anaesthesia. It is anticipated that these will be the subject of pilot studies before becoming more widely available.

Standards of Safe Practice (Chairman: Professor P. Hutton). The work of this working party has continued throughout the year. The intention is to produce a code of safe practice covering various aspects of anaesthetic care.

Limited life anaesthetic equipment (Chairman: Dr P.L. Jones). This joint working party with the British Anaesthetic and Respiratory Equipment Manufacturers Association (BAREMA) held its first meeting in July 1991. The remit of the working party is to consider all aspects of the use and re-use of limited life anaesthetic equipment such as breathing systems. It is anticipated that the working party will report in 1992.

29. Resuscitation Council UK (Association Representative: Dr P.J.F. Basket, President)

The Council is producing a manual for Advanced Cardiac Life Support (ACLS) which will form the basis for ACLS courses organised by the Council from late 1991 onwards. These courses will be analogous to Advanced Trauma Life Support courses organised by the Royal College of Surgeons.

Statements on various aspects of resuscitation have been produced and are available from the Honorary Secretary of the Resuscitation Council. Future ACLS guidelines will be formulated in conjunction with the European Resuscitation Council.

The Research working party is conducting a survey of cardiopulmonary resuscitation (CPR) in British hospital. The results will be published in late 1991. Other working parties continue to address the subjects of paediatric CPR, drowning and hypothermia and post resuscitation outcome.

A symposium will be held in 1991 with 'Teaching Resuscitation' as a major topic. The current Chairman of the Resuscitation Council is Dr T. Evans and Dr C. Robertson has been appointed Chairman-Elect to take office in 1992. The Honorary Secretary is Dr A. Handley, Consultant to the Accident and Emergency Department, Colchester.

30. European Resuscitation Council (Association Representative: Dr. P.J.F. Baskett, President)

The General Assembly of the European Resuscitation Council (ERC) was held in Brussels on 20 March 1991. Dr P.J.F. Baskett was elected as the first President in 1989 and continues in Office.

Many of the activities of the Council are accomplished through its working groups. The working group on Basic Life Support intends to produce a final report during 1992 with guidelines for practice, teaching programmes and audit. There will be close consultation with national resuscitation councils and societies in Europe, the American Heart Association, the Australian Resuscitation Council and the Canadian Heart and Stroke Association. Representatives of the ERC met representatives from the USA, Australia and Canada in Norway and London, and have compiled a glossary of agreed terms and a reporting template with suggested minimal and optimal data so that accurate audit comparisons can be made between services. The recommendations have been published in *Circulation* in May 1991. A universal report form for cardiac arrest events has been designed and will be widely promulgated after pilot trials are complete.

The ERC has adopted the journal *Resuscitation* as its official journal, and Dr D. Chamberlain has been appointed the European Editor. A Scientific Congress will be held jointly with the Resuscitation Council UK in Brighton in November 1992.

31. UEMS—Monospecialist Committee for Anaesthesia

(Association Representative: Dr W.R. MacRae, Honorary Treasurer)

During the past year the Committee for Anaesthesia has held three well attended meetings in Cardiff, Brussels and Strasbourg. Professor Barrier (*Paris*) continued as President.

The Committee has considered a wide range of matters particularly duration of training in anaesthesia and examinations. The variations in duration of training accepted by various countries of the EC were noted to be making it very difficult for doctors moving between countries to obtain recognition of their training. The question of uniformity of examinations and their standards throughout EC countries was raised again.

The response of the main UEMS Committee to these problems is a proposal that there be set up European Boards in each specialty to review the problems and to prepare guidelines. The setting up of European examinations in all specialties has also been proposed. Assurances have been received that the Monospecialist committees would have an input to the arrangements. A meeting between members of the Monospecialist Committee for anaesthesia and the Senate of the European Academy to consider these matters has been held and a further meeting is planned at the end of 1991.

The Committee is preparing outline recommendations for minimal standards of equipment and facilities required in all anaesthetising sites, and for the role of the anaesthetist in emergency services. The situation both in hospital and in the community are under study.

32. College of Anaesthetists' Quality of Practice Committee

(Association Representative: Dr J.E. Charlton, Honorary Secretary)

The College of Anaesthetists' Audit Committee has been renamed the Quality of Practice Committee and is now chaired by Dr J.C.

Stoddart. The Honorary Secretary has attended meetings of this Committee as the nominee of the Association. Deputies are not permitted on this Committee. Sufficient funding has been received from the Department of Health to enable the College to engage an Administrative Assistant, most of whose duties are taken up by the Committee.

Activities which are being organised or supported by the Committee are record keeping, a confidential enquiry into brain damage and/or cardiac arrest after anaesthesia, critical incident reporting, neurological complications of obstetric epidural anaesthesia, use of intensive therapy services and the retrieval of data relating to the incidence of chronic pain.

Several of these studies are self-generated from within the Committee, but requests for funding and advice concerning audit projects from Fellows are considered as well. Such applications will now be peer reviewed before submission to the Committee at meetings held twice yearly. The Annual Report of this Committee indicates that advice on planning and information relating to audit methodology is welcomed and supported when possible. The Chairman of the Committee has stated this usually takes the form of advice to audit groups having problems with management. Some requests for information about audit techniques have been answered by the Chairman.

The Committee has issued advice concerning audit and confidentiality. It has considered the medico-legal implications of audit and has made recommendations for the handling of audit data and the conduct and recording of audit meetings.

Appendix A

Composition of Council, its Sub-Committees and Working Parties

Council

Five meetings held, attendance in brackets.

Officers: Dr P.J.F. Baskett, President (5); Dr M.M. Burrows, Immediate Past President (3); Air Cdre C.A.B. McLaren, Vice President (5); Dr P. Morris, Vice President (5); Professor Sir Keith Sykes, Vice President (5); Dr W.R. MacRae, Honorary Treasurer (5); Dr J.E. Charlton, Honorary Secretary (5); Dr W.L.M. Baird, Immediate Past Honorary Secretary (5); Dr R.S. Vaughan, Assistant Honorary Treasurer (5); Dr M. Morgan, Editor (4).

Elected Members: Professor A.R. Aitkenhead (5); Dr Lauren G. Allan (4); Dr Margaret L. Heath (5); Professor P. Hutton (4); Dr S.M. Lyons (5); Dr I. McLellan (5); Dr Anna-Maria Rollin (4); Dr R.L. Marks (4); Dr Anne J. Sutcliffe (4); Dr R.M. Weller (5); Dr P.J. Heath, GAT (until April 1991) (3); Dr Elizabeth M. Spencer, GAT (4); Dr Susan M. Geddes, GAT (from April 1991) (1).

Co-opted Members: Dr J.N. Horton, Editor, *Anaesthesia News*; Dr D.C. Moriarty, Dean, Faculty of Anaesthetists, RCS in Ireland; Brigadier J.R. Restall, Armed Forces Representative; Dr D.D. Riordan, Convenor, Irish Standing Committee; Professor M. Rosen, President, College of Anaesthetists; Professor M.D. Vickers, President, European Academy of Anaesthesiology; Dr J.S.M. Zorab, President, WFSA.

Advisory Committee

Four meetings held, attendance in brackets.

Dr P.J.F. Baskett, *Chairman* (4); Dr W.L.M. Baird (3); Dr J.E. Charlton (4); Dr Margaret L. Heath (4); Dr S.M. Lyons (4); Dr W.R. MacRae (3); Dr M. Morgan (4); Professor M. Rosen (4); Dr R.S. Vaughan (4); Dr R.M. Weller (3); Dr P.J. Heath, GAT (until April 1991) (2); Dr Elizabeth M. Spencer, GAT (from April 1991) (2).

Officers of the Association are ex-officio members of all committees and working parties

Anaesthetists in Training

Dr P.J. Heath, *Chairman* (until April 1991); Dr Elizabeth M. Spencer, Chairman (from April 1991); Dr M.W. Platt, *Vice Chairman*, Dr Elizabeth M. Spencer, *Secretary* (until April 1991); Dr Susan M. Geddes, *Secretary* (from April 1991); Dr P. Morris, Council representative; Dr M.S. Rocheteau, HJSC representative; Dr J.J. Owens, Irish Committee representative (until April 1991); Dr D.W.P. Mannion, Irish Committee representative (from April 1991); Dr Susan M. Anderson (until April 1991); Dr Susan M. Geddes (until April 1991); Dr A.P.L. Goodwin (from April 1991); Dr J. Leigh (from April 1991); Dr A.B. Lumb (from April 1991); Dr I. McMenemin (until April 1991); Dr J.N. Shephard; Dr Rebecca J. Sparling (from April 1991); Dr H.St John Gray.

Standing Committee Republic of Ireland

Dr D.D. Riordan, *Convenor*; Dr W.P. Blunnie, *Deputy Convenor*; Dr P.J. Breen, *Secretary*; Dr J.F. Cahill, *Treasurer and Assistant Secretary*, Dr P.J. Fitzgerald, Dr T.N. Fogarty, Dr H.A.M. McCafferty, Dr G.C. McDowell, Dr A.J. McShane, Dr Kate O'Loughlin, Dr D. O'Toole, Dr D.J. Warde, Professor R.S.J. Clarke, Co-opted member, Dean Elect of Faculty; Dr J.J. Owens, Co-opted member (until April 1991), GAT; Dr D.W.P. Mannion, Co-opted member (from April 1991), GAT.

Editorial Board

Dr P.J.F. Baskett, *Chairman*; Dr M. Morgan, *Editor*; Professor A.R. Aitkenhead, Dr R. Greenbaum, Dr M. Harmer, Dr Rosemary A. Mason. Dr D.E.F. Newton, *Assistant Editors*; Dr Anna-Maria Rollin, Representative of Council; Air Cdre C.A.B. McLaren, Representative of Council; Dr H.St John Gray, Representative of GAT; Mr E. Warburton, Co-opted member, Honorary Financial Adviser; Mrs Joan Fujimoto, Co-opted member, Academic Press; Miss Jane Lawrence, Co-opted member, Academic Press.

Anaesthesia News Management Board

Dr P.J.F. Baskett, *Chairman*; Dr Margaret L. Heath, Dr J.N. Horton, *Editor*; Dr Anna-Maria Rollin.

Anaesthesia Management News

Professor M.D. Vickers, *Editor*; Dr Lauren G. Allan, *Assistant Editor*.

Education and Research

Dr J.A.W. Wildsmith, *Chairman*; Professor A.R. Aitkenhead; Dr Lauren G. Allan; Dr S.M. Lyons; Air Cdre C.A.B. McLaren; Dr I. McLellan; Dr Anna-Maria Rollin; Dr R.M. Weller; Dr Susan M. Anderson, GAT (until April 1991); Dr A.P.L. Goodwin, GAT (from April 1991).

Safety Committee

Professor P. Hutton, *Chairman*; Professor A.P. Adams, Chairman, WFSA Safety Committee; Dr Lauren G. Allan, Dr R. Greenbaum, Dr Margaret L. Heath, Air Cdre C.A.B. McLaren, Dr R.L. Marks, Dr P. Morris, Dr N.I. Newton, Dr Anne J. Sutcliffe, Professor Sir Keith Sykes, Dr P.W. Thompson, Dr P.J. Heath, GAT (until April 1991); Dr Rebecca J. Sparling, GAT (from April 1991); Dr Kate Allsopp, Medical Defence Union; Mr L.W.M. Arrowsmith, Department of Health; Mr C. Bray, Department of Health; Dr Juliet M. Davies, Medical Protection Society; Mr M.F. Freeman, Chairman, BAREMA; Dr I.G. Simpson, Joint Co-ordinating Committee, Medical Defence Organisations; Dr Helen Sutton, Department of Health.

Finance Committee

Dr W.R. MacRae, *Chairman*; Professor A.R. Aitkenhead, Dr I. McLellan, Dr R.L. Marks, Professor M. Rosen, Mr E. Warburton, Honorary Financial Advisers; Ms Pat Plant, Financial Assistant.

International Relations Committee

Dr S.M. Lyons, *Chairman*; Dr Lauren G. Allan, Dr M. Dobson, Dr R.J. Eltringham, WFSA Education Committee; Dr M.T. Inman, Dr R.L. Marks, Dr P. Morris, Dr D.A. Saunders, Bernard

Johnson Adviser; Dr R.M. Weller, Dr J.A.W. Wildsmith, Dr J.S.M. Zorab, President WFSA; Dr M.W. Platt, GAT (until April 1991); Dr A.P.L. Goodwin, GAT (from April 1991).

Representatives from: Overseas Development Administration, Bureau for Overseas Medical Service, British Council, Inter-varsity Council, Committee for International Co-operation in Higher Education, Voluntary Services Overseas, Appropriate Health Resources and Technologies Action Group.

Private Practice

Dr R.M. Weller, *Chairman*; Dr E.B. Lewis, Dr S.M. Lyons, Dr I. McLellan, Dr Anna-Maria Rollin, Dr Anne J. Sutcliffe, Dr I. Verner.

Museum, Library and Archives Sub-committee

Dr T.B. Boulton, *Honorary Archivist and Chairman*; Dr D.J. Wilkinson, Honorary Curator, Charles King Collection of Historical Apparatus; Dr I. McLellan, Honorary Librarian; Dr Audrey Eccles, ICI Archivist/Librarian; Dr Aileen K. Adams, Honorary Archivist, College of Anaesthetists; Dr Ghislaine Lawrence, Science Museum.

1992 Diamond Jubilee Planning Committee

Dr P.J.F. Baskett, *Chairman*; Dr M.M. Burrows, Dr I. McLellan, Dr J.F. Nunn, Dr I. Verner, Dr R.M. Weller, Dr J.A.W. Wildsmith, Dr J.S.M. Zorab.

Specialist Societies

Chairman, President; Representatives from: Age Anaesthesia Association, Association of Cardiothoracic Anaesthetists, Association of Dental Anaesthetists, Association of Paediatric Anaesthetists of Great Britain and Ireland, College of Anaesthetists, Society for Computing and Technology in Anaesthesia, European Society of Regional Anaesthesia–UK Committee, History of Anaesthesia Society, Intensive Care Society, Group of Anaesthetists in Training, Neuroanaesthetists' Travelling Club, Obstetric Anaesthetists' Association, The Pain Society of Great Britain and Ireland, Plastic Surgery and Burns Anaesthesia, Resuscitation Council UK.

Working Party on Assistance for Anaesthetists

Dr M.M. Burrows, *Chairman*; Dr Margaret L. Heath, *Secretary*; Dr D.S. Arthur, Dr J. Edmonds-Seal, Dr S.M. Lyons, Dr P. Morris, Professor M.D. Vickers.

Joint Working Party on Services for Chronic Pain Relief

Dr J.E. Charlton, *Chairman*; Dr A.W. Diamond, *Secretary*; Dr K. Budd, The Pain Society; Dr F.R. Ellis, College of Anaesthetists; Dr P.J.D. Evans, The Pain Society; Dr D.J. Hatch, College of Anaesthetists; Dr R.L. Marks.

Working Party on High Dependency Units

Dr J.A.W. Wildsmith, *Chairman*; Dr Gillian Hanson, Intensive Care Society; Dr S.M. Lyons, Dr D.L. Paul, GAT; Dr M.G. Pearson, Consultant Physician, *Liverpool*; Dr G.A.D. Rees, Consultant Anaesthetist, *Cardiff*; Dr G.S. Routh, Intensive Care Society; Mrs R. Wilkinson, RCN; Mr G.G. Youngson, Consultant Surgeon, *Aberdeen*.

Working Party on the Role of the Anaesthetist in the Emergency Service

Dr P.J.F. Baskett, President, *Chairman*; Professor P. Hutton, Dr C.R.D. Laird, GAT; Professor J. Norman, College of Anaesthetists; Mr D. Skinner, Dr R. Sleet, Dr Anne J. Sutcliffe, Dr R.M. Weller.

Working Party on Media Liaison

Dr Margaret L. Heath, Dr S.M. Lyons, Dr Anna-Maria Rollin.

Working Party on Standards of Safe Practice

Professor P. Hutton, *Chairman*; Professor A.P. Adams, Dr Juliet M. Davies, Medical Protection Society; Dr R.J. Eltringham, Dr M.W. Platt, GAT; Dr J.A.W. Wildsmith.

Working Party on Limited Life Anaesthetic Equipment

Dr P. Jones, *Chairman*; Dr Margaret L. Heath, Association representative; Dr Anne J. Sutcliffe, Association representative; Dr D. Barrow, BAREMA; Mr B.R. Sugg, BAREMA; Dr D. Fox, Mediplan-DAR Ltd; Miss Deborah Litton, Intersurgical Ltd; Mr L. Small, NHS Procurement Directorate; Miss J. Grieves, NATN representative.

Working Party on Departmental Accommodation

Dr W.L.M. Baird, *Chairman*; Dr Lauren G. Allan, Dr R.W. Buckland, Mrs Barbara Burgess, Dr Jean Lumley, College of Anaesthetists; Mrs Linda Reid, Dr Anna-Maria Rollin, Dr P.V. Scott, GAT representative.

Working Party on Workload for Non-consultant Career Grades

Dr P. Morris, *Chairman*; Dr Kate Bullen, Dr S.H. Kothari, Dr S.M. Lyons, Dr Anna-Maria Rollin, Dr J.N. Shephard, GAT.

Working Party on HIV and Hepatitis B

Dr J.F. Searle, *Chairman*; Dr Lauren G. Allan, Mr Peter Erridge, Dr A.P. Rubin, College of Anaesthetists; Professor D.J. Jefferies, Dr M.M. Burrows, Dr I. McLellan, GAT representative.

The Association of Anaesthetists of Great Britain and Ireland is represented on the following committees/bodies

Anaesthetics Sub-committee, CCSC

Dr S.M. Lyons, *Chairman*; Dr Lauren G. Allan, Dr J.E. Charlton, Dr R.M. Weller, Dr Susan M. Geddes, GAT (until April 1991); Dr H.St John Gray, GAT (from April 1991).

Postgraduate Study Day

Professor A.R. Aitkenhead, Dr J.E. Charlton, Professor Sir Keith Sykes, Professor A.P. Adams, College of Anaesthetists; Dr K. Budd, College of Anaesthetists; Professor C.J. Hull, College of Anaesthetists.

Resuscitation Council UK/European Resuscitation Council

Dr P.J.F. Baskett

UEMS Representative

Dr W.R. MacRae

Association Representative on College of Anaesthetists' Quality of Practice Committee

Dr J.E. Charlton

Manpower Advisory Panel

Dr R.S. Vaughan, Dr Elizabeth M. Spencer, GAT.

Joint Committee for Higher Training of Anaesthetists

Dr W.L.M. Baird, Dr J.A.W. Wildsmith, Dr Susan M. Geddes, GAT.

Trustees of the Anaesthetists' Academic Foundation

Dr P.J.F. Baskett.

Technical Exhibitors Co-ordinators

Dr R.S. Vaughan, Dr F.L. Roberts.

Association Exhibition Stand Coordinators

Dr Wendy E. Scott, Dr R. Jane Chesnut.

National Confidential Enquiry into Perioperative Deaths

Dr M.M. Burrows, Dr J.N. Lunn.

Association Representatives on College of Anaesthetists Manpower Advisory Panel, Working Group to review unfilled consultant posts

Dr Margaret L. Heath, Dr R.S. Vaughan, Professor Sir Keith Sykes.

Association Representative on College of Anaesthetists Fund Raising Committee

Dr W.L.M. Baird.

Association Representative on National Health Service Training Authority ODA Training Project (NHSTA)

Dr Margaret L. Heath.

Appendix B

Future Meetings

1991

12 October: Continuing Medical Education Study Day (Postgraduate Study Day), Royal College of Surgeons, London.

1992

10–11 January: Diamond Jubilee Scientific Meeting and Technical Exhibition, Queen Elizabeth II Conference Centre, London.

1–3 April: Group of Anaesthetists in Training Annual Scientific Meeting and Linkman Conference, The Victoria Rooms, Bristol.

9–11 September: Annual Scientific Meeting, Linkman Conference and Technical Exhibitions, Bournemouth International Centre.

17 October: Continuing Medical Education Day, Royal College of Surgeons, London.

1993

21–23 April: Group of Anaesthetists in Training Annual Scientific Meeting and Linkman Conference, Octagon Centre, Sheffield.

22–24 September: Annual Scientific Meeting, Linkman Conference and Technical Exhibition, Scottish Exhibition and Conference Centre, Glasgow. Joint meeting with Canadian Anaesthetists' Society.

1994

April: Group of Anaesthetists in Training Scientific Meeting and Linkman Conference, Newcastle upon Tyne.

7–9 September: Annual Scientific Meeting, Linkman Conference and Technical Exhibition, Brighton Conference Centre.

1995

April: Group of Anaesthetists in Training Annual Scientific Meeting and Linkman Conference, Leicester.

13–15 September: Annual Scientific Meeting, Linkman Conference and Technical Exhibition, International Convention Centre, Birmingham.

Appendix C

Association Linkmen

Names are grouped according to Regional Health Authority (Area in Scotland); the order of names within each group is arbitrary and without significance.

England

Northern (R.H.A. 1)

M. Berry (*Hartlepool*); B. Dennison (*South Tees*); R. Goodwin (*Durham*); D.C. Townsend (*South West Durham*); K.S. Cameron (*North West Durham*); C. Beeton (*Darlington*); I. Anderson (*Northumberland*); M.R. Bryson (*Newcastle Central Sector*); I.H. Shaw (*Newcastle Western Sector*); O.G.W. Weldon (*Newcastle Eastern Sector*); S.K. Greenwell (*North Tynside*); G. Harris (*North Tees*); R.M. Freeman (*Gateshead*); R. Gautam (*South Tyneside*); L.J. Mackay (*Sunderland*); J.N. Hodkinson (*South Cumbria*); D.M. Watson (*West Cumbria*); K.W. Nightingale (*East Cumbria*).

Yorkshire (R.H.A. 2)

T.D. Biswas (*Pontefract*); S. Firn (*Wakefield*); S.R. Swindells (*Leeds East*); J.S. Gibson (*Leeds West*); L.A. Sharaf (*Huddersfield*); S.A. Siddiqui (*Calderdale*); J.A. Robertson (*Airedale*); G.I. MacWhirter (*Harrogate*); R.G. Wheatley (*York*); G.T. Whitfield (*Scarborough*); T.I.R. Williams (*Hull*); J.M. Clark (*Grimsby*); P.J. Bickford-Smith (*Bradford*); M. Evans (*Dewsbury*).

Trent (R.H.A. 3)

D.P. Cartwright (*South Derbyshire*); M.J. Wolfe (*North Derbyshire*); J.V.B. Mundy (*Sheffield*); J.E. Hunsley (*Sheffield North*); V. Boyd (*Rotherham*); B.R. Milne (*Doncaster*); P.S. Gadgil (*Barnsley*); C.J. Bowley (*Nottingham*); A.H.R. Spong (*North Lincolnshire*); M.D.R. Bexton (*South Lincolnshire*); A.G. Cole (*Leicester*); P. Smith (*Worksop*); P.T. Bull (*Central Nottinghamshire*).

East Anglia (R.H.A. 4)

P.J. Keep (*Norwich*); J.R.O. Jenkins (*Great Yarmouth and Waveney*); A.J. Barclay (*King's Lynn*); P.M. Benison (*Huntingdon*); C.W. Glazebrook (*Cambridge*); A.P. Gallimore (*West Suffolk*); D.J. Elliott (*East Suffolk*); J.M.F. Hartley (*Peterborough*).

North West Thames (R.H.A. 5)

D.J.C. Robinson (*St Mary's Paddington*); R.L. Hargrove (*Westminster Hospital*); P. Chakrabarti (*West Middlesex University Hospital*); M. Meurer-Laban (*Ealing*); D.A. Zideman (*Hammersmith Hospital*); B.G. Cameron (*Hillingdon Hospital*); P.M. Brodrick (*Mount Vernon Hospital, Hillingdon*); P. Forrester (*Charing Cross Hospital*); K.M. Konieczko (*Northwick Park*); E.S. Walsh (*Central Middlesex*); A.E.L. Nicol (*Barnet*); M.I. Carter (*Luton and Dunstable*); J. Hurst (*Bedford*); G.M. O'Sullivan (*Watford*); Z.P. Shah (*Welwyn Garden City, Hertford*); M.J. Boscoe (*Harefield Hospital, Middlesex*); W.J. Rickford (*N. Hertfordshire*); J.D. Hill (*Herts and Essex General Hospital, E. Hertford*); B.M. Dempsey (*Hounslow and Spelthorne*); N. Fletcher (*Barnet*).

North East Thames (R.H.A. 6)

A.R. Deacock (*Royal National Orthopaedic, Middlesex (NHS Trust)*); J. Ormrod (*University College Hospital*); D.J Wilkinson (*St Bartholomew's Hospital*); P.J. O'Shea (*The Royal London Hospital, Whitechapel (NHS Trust)*); S.A.I. Helwa (*Enfield*); M.S. Pegg (*Royal Free Hospital*); G.B. Rushman (*Southend*); R.W. Griffin (*Colchester*); J.L. Handy (*Mid Essex*); D.A. Thomas (*Harold Wood Hospital*); A.F. Naylor (*Basildon and Thurrock*); E.B. Javed (*Whipps Cross, Waltham Forest*); S.K. Hepton (*Barking, Havering and Brentwood*); D.V.A. Kalmanovitch (*Whittington Hospital*); T.D. McGhee (*Newham General Hospital*); N. Poobalasingham (*N. Middlesex*); D.J. Lightman (*Princess Alexandra Hospital, E. Hertford*).

South East Thames (R.H.A. 7)

B.G. Bradburn (*Canterbury and Thanet*); D.F. Senior (*Gravesend*); A.R. Thompson (*Hastings*); B. Steer (*Eastbourne*); E.A. Proctor (*Canterbury and Thanet*); E.B. Lewis (*Ashford, Kent/S.E. Kent*); K.H.P. Singh (*Dartford and Gravesham*); P.E. Daly (*Greenwich and Brook Hospital*); I.M. Corall (*King's College Hospital*); D.A. Young (*Bromley*); J.A. Mathias (*St Thomas's Hospital*); C.J. Barham (*East Grinstead*); D.A. Simpson (*Medway*); J.M. Lamberty (*Brighton*); D. Iyer (*Maidstone*); A.J. Porterfield (*Tunbridge Wells*).

South West Thames (R.H.A. 8)

I.K. Stanley-Jones (*Chertsey*); W.A.L. Rawlinson (*Mid Downs*); R.C. Brookes (*Croydon*); J.E. Robson (*Guildford*); H.R. Waters (*Worthing*); J.C. Missen (*Chichester*); W.A. Lindsay (*Merton and Sutton*); A.C. Thurlow (*St George's Hospital*); A-M. Rollin (*Epsom*); I.A. Sutherland (*Frimley Park Hospital*); R.M.H. Ratcliffe (*East Surrey*); L.S.St John Jones (*Crawley*); M.C. Thompson (*Cambridge Military Hospital, Aldershot*).

Wessex (R.H.A. 9)

K.J. Gill (*West Dorset (NHS Trust)*); K.J. Davies (*Winchester*); A.D. Logan (*Isle of Wight*); M.P. Tattersall (*Swindon*); D.T. Protheroe (*Bath*); A. Turrall (*Portsmouth*); D.A. Saunders (*Southampton*); K. Landon (*Newport, IOW*); P.D. James (*Basingstoke*); P.W.R. Smethurst (*Odstock*); P. Smyth (*Poole*).

Oxford (R.H.A. 10)

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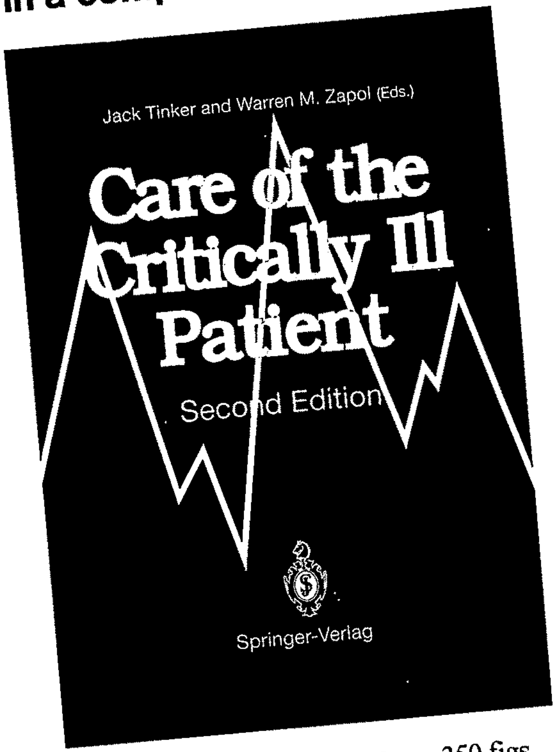
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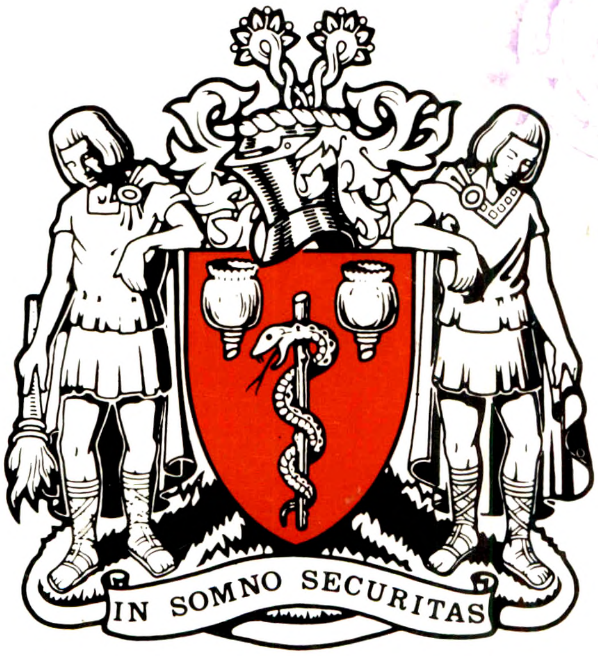
Anaesthesia

Journal of the Association of Anaesthetists of Great Britain and Ireland

Volume 47 Number 3 March 1992



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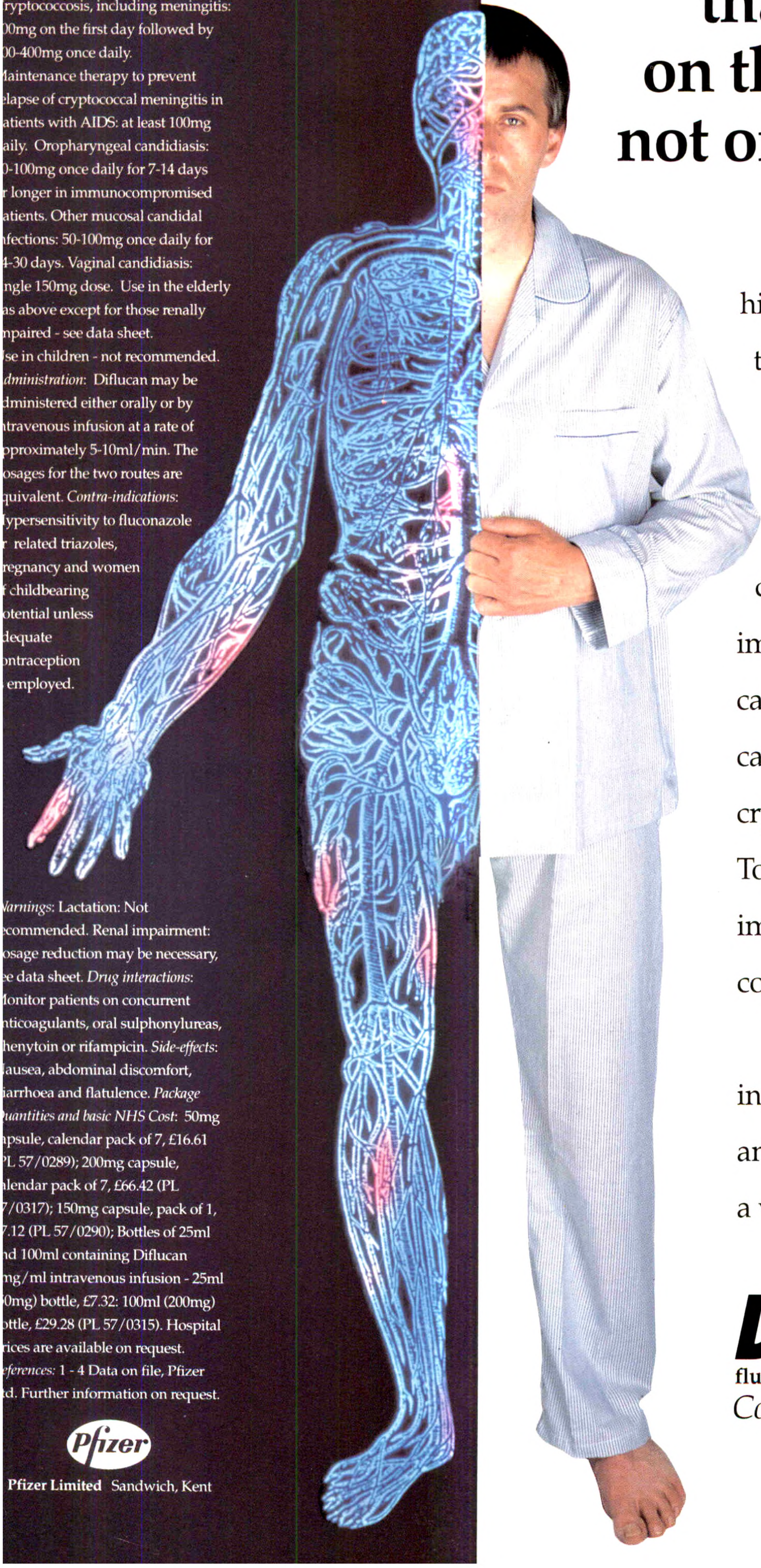

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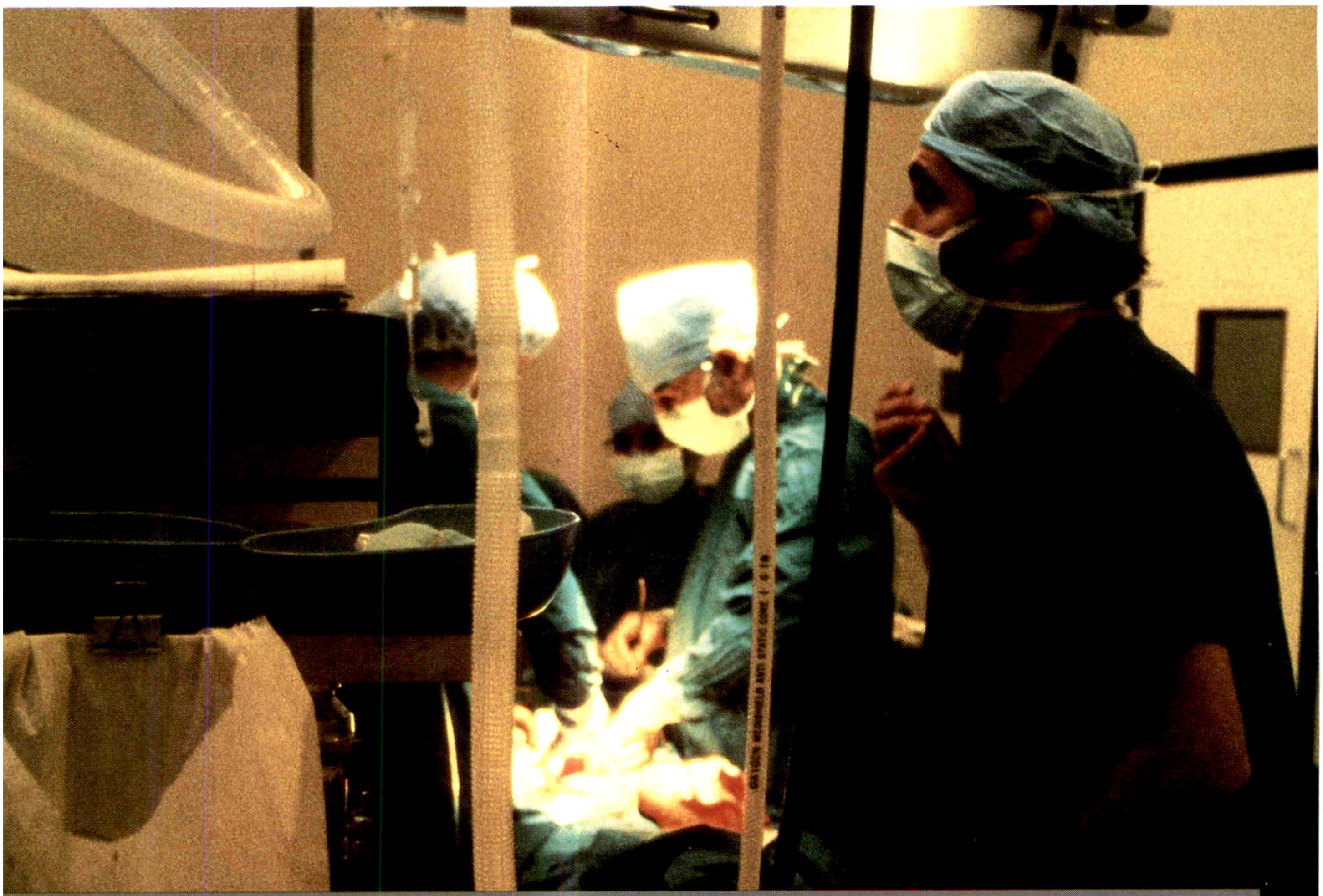

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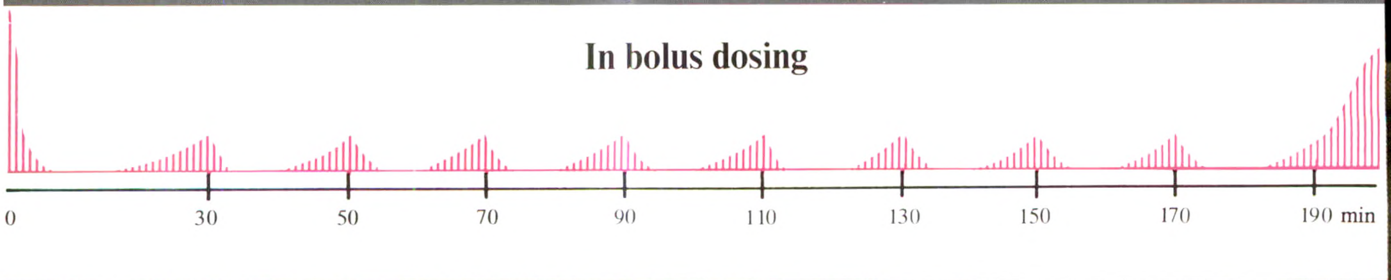

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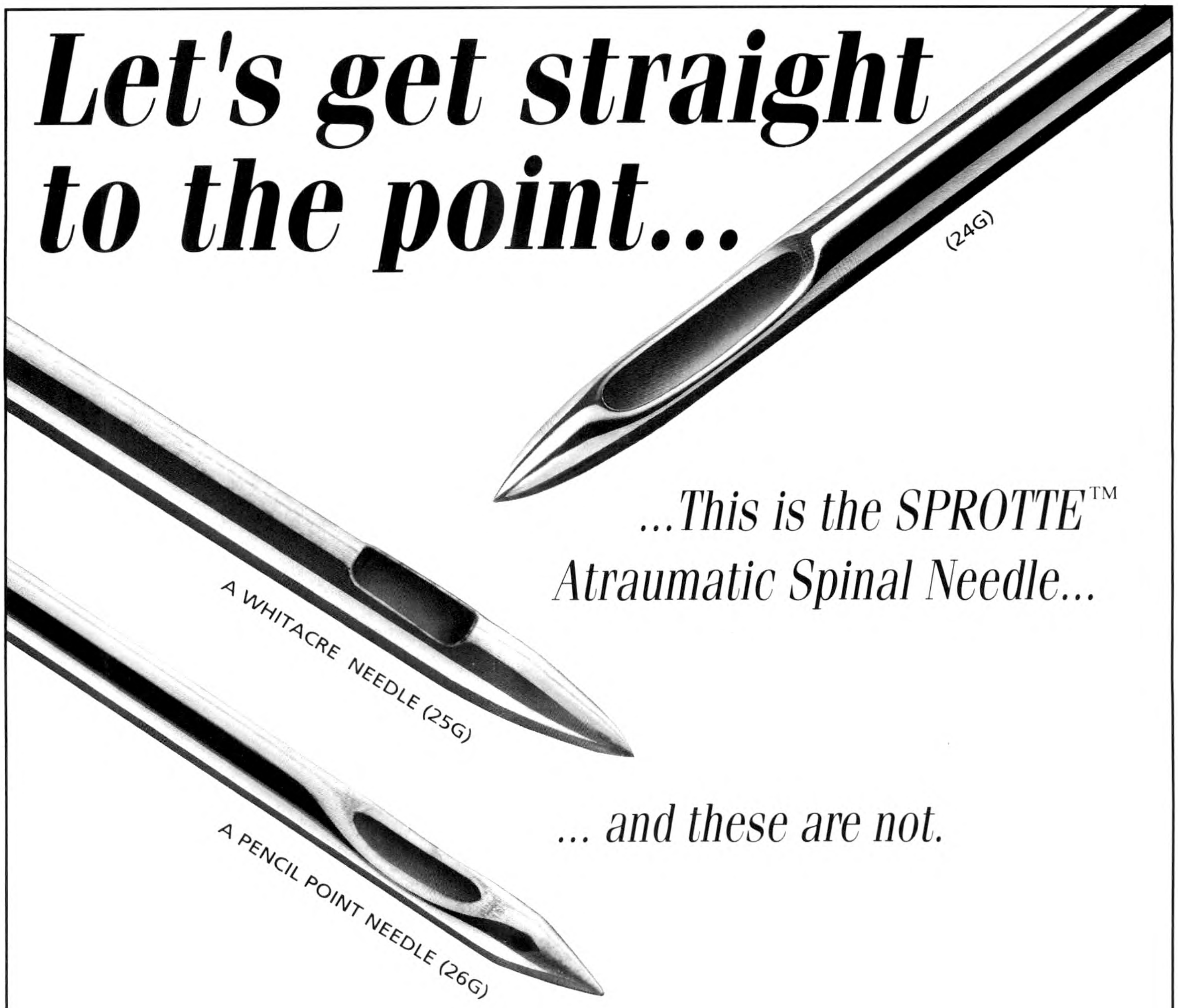

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(1) Cesarini et al. Anaesthesia (1990) 45:656-658

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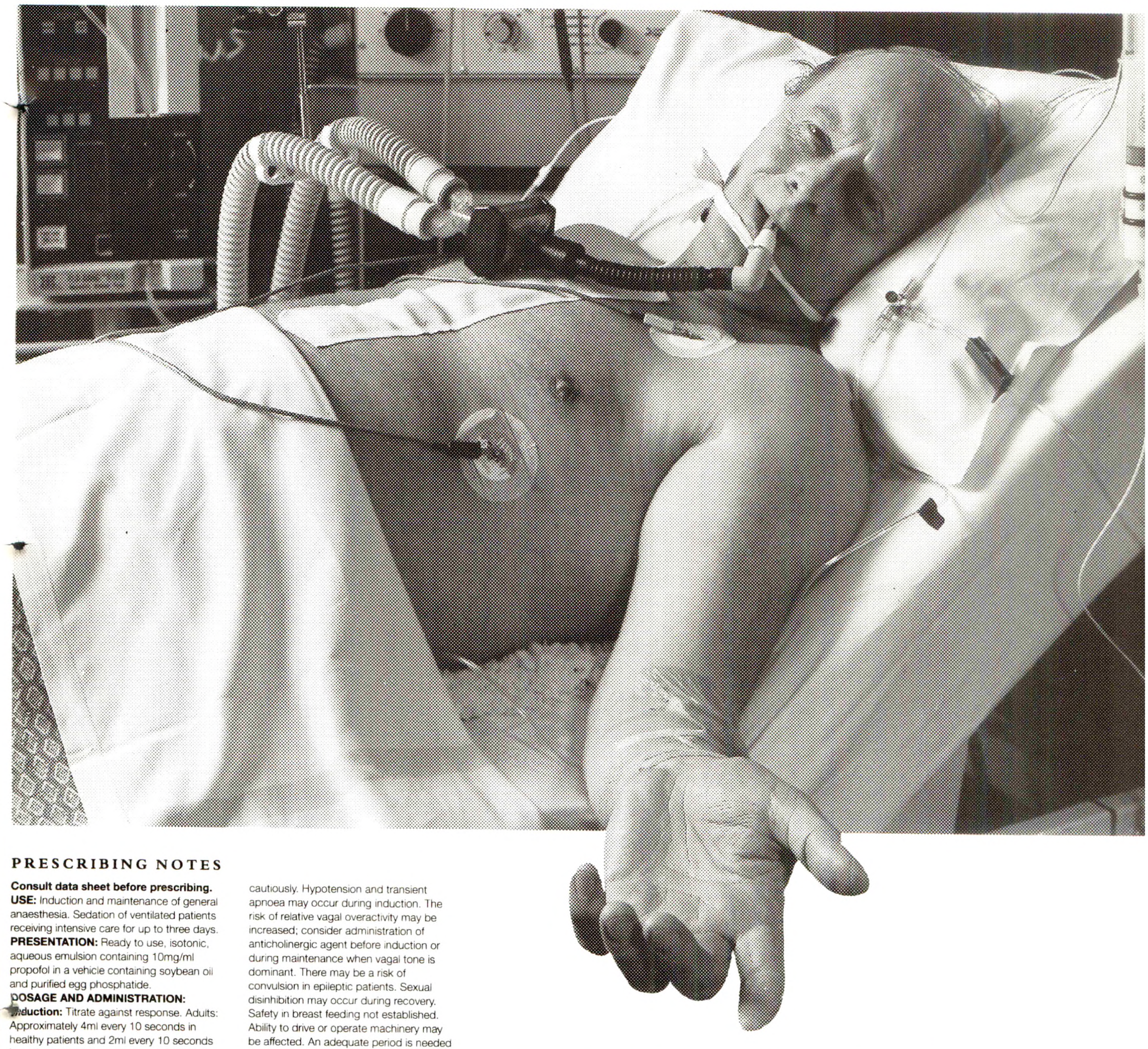

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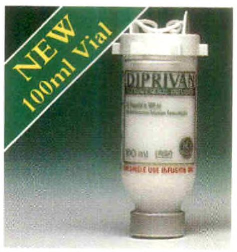

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Maintenance: Titrate against response. Adults: Usually 4 to 12mg/kg/hr. Alternatively repeat bolus injections of 25mg to 50mg (2.5 to 5.0ml) may be administered according to clinical need. Children over 3 years: Usually 9 to 15mg/kg/hr. Children under 3 years: not recommended.
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CONTRAINDICATIONS, WARNINGS, ETC: Contraindicated in allergy to 'Diprivan'. Not recommended in ECT. Do not use in pregnancy or for obstetric anaesthesia. Should be given only by those trained in anaesthesia or intensive care. Facilities for maintenance of airway, artificial ventilation and oxygen enrichment should be available. Caution in cardiac, respiratory, renal or hepatic impairment, in hypovolaemic or debilitated patients and in disorders of fat metabolism or conditions where lipid emulsions should be used cautiously. Hypotension and transient apnoea may occur during induction. The risk of relative vagal overactivity may be increased; consider administration of anticholinergic agent before induction or during maintenance when vagal tone is dominant. There may be a risk of convulsion in epileptic patients. Sexual disinhibition may occur during recovery. Safety in breast feeding not established. Ability to drive or operate machinery may be affected. An adequate period is needed prior to discharge to ensure full recovery. 'Diprivan' contains no antimicrobial preservative and supports the growth of micro-organisms. Administration must commence without delay after opening the container. Maintain asepsis for 'Diprivan' and all infusion equipment. 'Diprivan' and any equipment is for single use in an individual patient. Discard and replace infusion lines and reservoirs of 'Diprivan' at regular intervals during long-term maintenance or sedation in intensive care. Do not mix prior to administration with other agents or infusion fluids except 5% Dextrose. Do not administer via a microbiological filter.
SIDE EFFECTS: Epileptiform movements, including convulsions and opisthotonus, have occurred rarely in a temporal relationship to 'Diprivan'. Nausea, vomiting and headache in a small proportion of patients. Very rarely, clinical features of anaphylaxis, which may include bronchospasm, erythema and hypotension, have been reported with 'Diprivan'. Pain on injection in a proportion of patients. Discolouration of urine and venous sequelae are rare. Post-operative fever has been reported. Minimal evidence of excitation on induction.
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Anaesthesia, 1992, Volume 47, pages 193–195

Editorial

Peri-operative shivering

The occurrence of shivering after general anaesthesia has been recognised for many years, and has been variously described as 'pentothal shakes', 'halothane shakes', 'shivering', 'postoperative spasticity', and 'spontaneous postanaesthetic tremor'. The use of these imprecise terms displays our lack of understanding of the physiological mechanisms behind the phenomenon. Some authors have drawn a distinction between the occurrence of increased muscle tone or spasticity before the patient is truly awake and 'shivering' that occurs when the patient is conscious. Apart from the need to recognise the wide range of abnormal neurological signs that may be present during recovery from anaesthesia, and which are not necessarily part of the phenomenon of shivering, there seems little justification for this arbitrary division.

If we consider all forms of involuntary muscular activity in the recovery phase as part of the same syndrome, then the reported incidence of shivering following general anaesthesia varies between 5 and 65% [1–9], and there is some evidence that the incidence varies with anaesthetic technique [4, 9] and with the duration of the procedure [9]. It is not known how many patients suffer harm as a result of shivering in the recovery room, but reported consequences include raised oxygen consumption [7, 10, 11], hypoxaemia [7], raised carbon dioxide production [11], lowered mixed venous oxygen saturation [12] and lactic acidosis [11]. Minute ventilation rises in association with the increase in carbon dioxide production [10, 11]. Cardiac output may rise in proportion to oxygen consumption, but if it is unable to do so severe mixed venous desaturation with consequent arterial hypoxaemia will result [10]. Thus postoperative shivering may accentuate factors such as respiratory depression, periods of airway obstruction and the excretion of nitrous oxide which cause hypoxaemia in the recovery period. Shivering has also been reported to raise intra-ocular pressure [2] and interfere with monitoring [13].

Conventional wisdom has it that shivering after general anaesthesia is a consequence of heat loss incurred during the operative procedure, encouraged by the use of volatile agents. In fact the incidence of shivering after general anaesthesia correlates poorly with body temperature [3, 4, 14, 15]. Whilst there may be doubt that hypothermia *per se* is a causative factor, it is true that hypothermic patients shiver for longer than those who are normothermic on entry into the recovery room [14]. Sessler *et al.* [16] have presented evidence that the electromyographic characteristics of shivering after general anaesthesia differ from those of cold-induced shivering. They studied the EMGs of nine women recovering from isoflurane anaesthesia and compared these with EMGs obtained from normal unanaesthetised subjects during cold-induced shivering. This study design is unfortunate because it fails to allow comparison between normothermic and hypothermic individuals at any given end-tidal isoflurance concentration. Indeed most of their subjects remained hypothermic throughout the study period and the possibility remains that their result arose from modification of normal thermogenic shivering by residual anaesthesia.

Patients also shiver in association with regional anaesthesia. During epidural anaesthesia the incidence of shivering is between 33% and 66% [17, 18]. This should be compared with an incidence of 10% during normal labour without epidural anaesthesia [19]. Shivering in association with epidural anaesthesia is reported to resemble true thermogenic shivering [20]. It is generally regarded as a nuisance rather than as a factor in morbidity, although it has been reported to cause significant distress [21]. In theory shivering during epidural anaesthesia in labour might increase maternal oxygen demand and have adverse effects upon maternal and fetal biochemistry, but there is no evidence to suggest that this happens in practice.

More rational treatment will come with better understanding of the physiology and aetiology of postanaesthetic shivering. If peri-operative shivering is related to hypothermia, then warming the patient and avoiding hypothermia should abolish shivering. In support of this Pflug *et al.* [15] demonstrated that active warming abolished shivering in a group of patients undergoing general anaesthesia. To achieve this, inspired gases were humidified and warmed to 42–47°C and the patients were insulated from the environment. The operating and recovery rooms were maintained at 23°C. This aggressive management may not be widely applicable. Mekjavic and Eiken [22] reported that radiant heat applied to the facial area reduced shivering in seven subjects who had been exposed to an ambient air temperature of 3°C for one hour. Shivering abated and re-appeared in accordance with the maximum rate of change of chin temperature, and they suggested that the trigeminal region provides an important input to thermoregulatory responses. In an anaesthetised primate model, Murphy *et al.* [23] showed that radiant heat stopped shivering without affecting core temperature. Subsequent experiments in obstetric patients [24] following either general anaesthesia or regional techniques showed that radiant heating abolished shivering in 22 of 30 subjects. Shivering resumed when the radiant heat was removed and could be abolished again by re-application. In four of the patients in whom shivering did not stop, its severity was reduced. In a further series of experiments [24] the effect of radiant heating was compared with that of application of a warm blanket, and was found to be superior. Thus there would seem no doubt that shivering can be influenced by manipulation of thermal inputs, even though the incidence of shivering may be unrelated to body temperature. This should tell us something about the physiology of peri-operative shivering, and lends support to the idea that it is true thermoregulatory shivering, the expression of

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which is modified by residual anaesthesia. Whether radiant heating would be a cost effective means of treating peri-operative shivering in all our recovery rooms is unclear, and would entail considerable capital expenditure.

Whilst manipulation of thermal inputs may not be entirely satisfactory, drug therapy may offer a simple cost-effective solution. Methylphenidate, a psychostimulant related to amphetamine, was shown to abolish peri-operative shivering in a series of 1000 patients undergoing halothane anaesthesia [25]. There was no control group, but personal experience suggests that between 60 and 100 patients would have shivered in an untreated group of similar size. Doxapram, an analeptic commonly used as a respiratory stimulant, has been shown to be effective [8] if given as an intravenous bolus of 1.5 $mg.kg^{-1}$. Perhaps the most hope for simple therapy is offered by the opioids. Pethidine 25 mg given as an intravenous bolus is effective in abolishing between 66 and 89% of episodes of peri-operative shivering [12, 26–28]. Butorphanol is also reported to be effective [29] but fentanyl and morphine are no better than control [28]. Pethidine is effective when given by the epidural route for shivering associated with epidural anaesthesia, as are fentanyl and sufentanil [18, 30–32]. If, as suggested, the phenomenon of peri-operative shivering relates to differential rates of recovery of the spinal cord and higher centres [17], then the action of the cerebral stimulants might be understandable. The action of the opioids remains a mystery. Those that are effective are so in low doses, suggesting specificity of action, but why some should be active when other similar agents are not is unexplained. In all of these observations lie clues to the physiology of peri-operative shivering.

It has recently been suggested that pharmacological management of peri-operative shivering may be inappropriate if applied to all patients, because some may be hypothermic [33]. It is clear that not all shivering patients are hypothermic, and there is evidence that shivering patients warm at the same rate as those who are not shivering [3]. This suggests that peri-operative shivering is not beneficial, and the possible harmful effects are well documented. With the ability to provide simple and effective treatment in the controlled environment of a recovery room, surely it is better to avoid the consequences of shivering and treat both shivering and hypothermia as appropriate?

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Editorial notices

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Anaesthesia, 1992, Volume 47, pages 196–198

Peripartum changes in gastric emptying

B. K. SANDHAR, R. H. ELLIOTT, I. WINDRAM AND D. J. ROWBOTHAM

Summary

Applied potential tomography was used to measure changes in gastric emptying during the peripartum period. Gastric emptying was measured sequentially in each of 10 healthy patients at 37–40 weeks gestation, 2–3 days postpartum and after the 6-week postnatal assessment (control). Mean (SD) times to 50% emptying were 15 (6.05), 11 (5.9) and 15 (5.5) min, respectively. There was no statistically significant change in gastric emptying as a result of pregnancy in this group of women. Retrospective power analysis (assuming $\alpha = 0.05$ and $\beta = 0.20$) shows the study design was adequate to detect a difference of 8 min.

Key words

Gastrointestinal tract; gastric emptying.
Measurement techniques; applied potential tomography.
Obstetrics; gastric physiology.

Delayed gastric emptying may increase the risk of inhalation of gastric contents during anaesthesia. Various different methods have been used to measure gastric emptying in pregnant women and these have produced conflicting results. During pregnancy, X ray and scintigraphic techniques [1–3] are contraindicated and changes in pharmacokinetic parameters during pregnancy may affect solute absorption techniques such as paracetamol [4,5]. Ultrasound is a safe, reliable technique but requires skilled personnel and expensive equipment [6].

The purpose of this study was to follow the individual changes in gastric emptying during pregnancy using applied potential tomography (APT) and to compare this with the patient's own control values obtained after the 6-week postnatal assessment.

Methods

Applied potential tomography

Applied potential tomography generates tomographic images of the resistivity of gastric contents using electrodes placed around the epigastrium. Following the ingestion of a test meal, changes in resistivity are measured. Sixteen electrodes are placed around the abdomen at the level of the eighth costal cartilage (at the level of the gastric fundus or body). An alternating current (1 mA, 50 kHz) is passed between two opposite electrodes and the potential differences between the remaining pairs are measured. During the measurement cycle, each pair of electrodes act in sequence as drive electrodes and a total of 208 measurements are made in 100 ms. The effects of respiratory movements are removed by summating data from 150 cycles. Measurements are made before, and at 1 min intervals after, the test meal.

Data are stored on disc by a Nimbus RM computer and a cross-sectional image of the change in resistivity is produced incorporating changes in resistivity 4 cm above and below the plane of the electrodes. The area on the image representing the stomach is visible clearly and changes in resistivity with time within this area are calculated (Fig. 1).

Gastric secretion of hydrogen ions after ingestion of a test meal may affect resistivity measurement significantly. Therefore, it is necessary to administer a histamine type-2-receptor antagonist prior to the measurement of gastric emptying with APT. Ranitidine was used in this study.

The measurement of gastric emptying by APT has been shown to correlate very closely with scintigraphic techniques [7].

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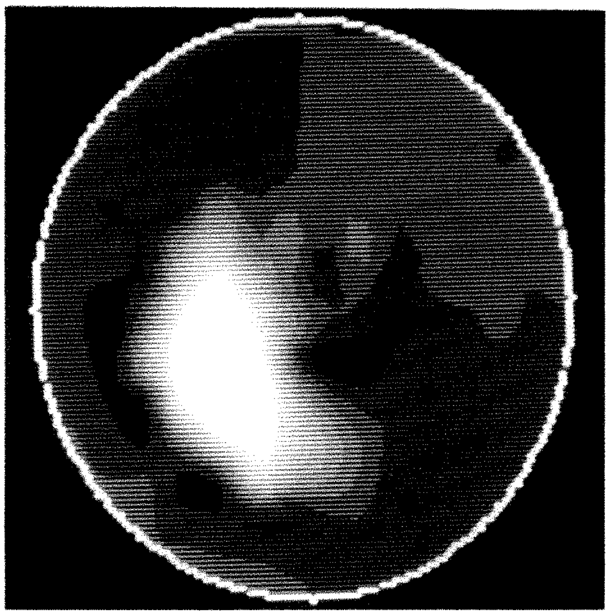

Fig. 1. Typical image of stomach contents produced by applied potential tomography in a patient in this study.

Study design

The study was approved by the hospital Ethics Committee and written informed consent was obtained from each woman. Healthy pregnant women taking no medication and with no apparent obstetric complications were recruited. Gastric emptying was measured at 37–40 weeks gestation, 2–3 days postpartum and 6 weeks postpartum. If necessary, the latter measurement was delayed until breast feeding had ceased.

At each measurement, the woman was fasted for 4 h and given ranitidine 150 mg orally 2 h before the study. The electrodes were placed around the upper abdomen and a reference value of resistivity was obtained. The woman was then given a drink of distilled water 400 ml and APT measurements were taken at 1 min intervals for 30 min during which the woman relaxed in the sitting position. Changes in the total resistivity of stomach contents were plotted against time and the time to 50% emptying (T_{50}) recorded.

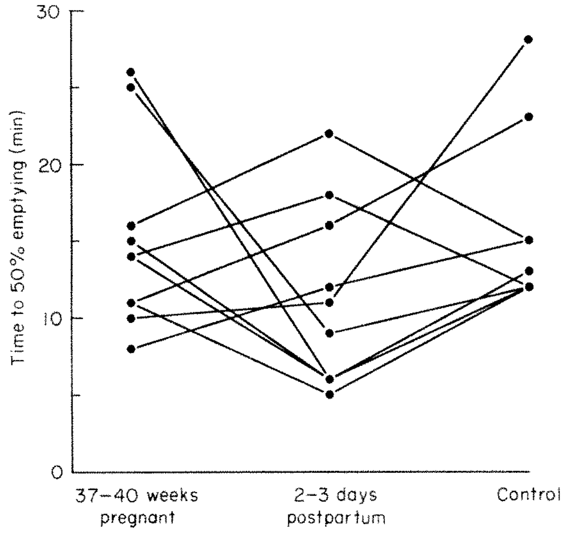

Fig. 2. Individual times to 50% emptying (min) in 10 patients.

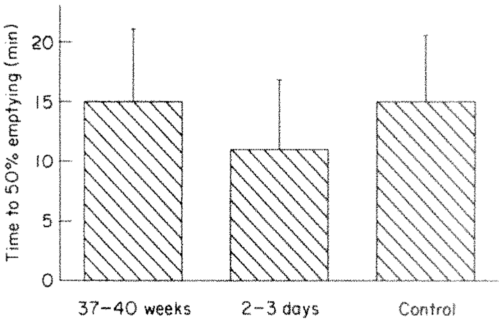

Fig. 3. Mean (SEM) times to 50% emptying (min). There were no significant differences.

Statistical analysis

Data were tested for normality using the goodness of fit test and analysis was performed using analysis of variance for matched data.

Results

Fourteen women were recruited to the study but four were later withdrawn because delivery was by Caesarean section.

Mean (SD) age and weight of the women was 27.3 (0.5) years and 65.8 (9.4) kg. T_{50} values obtained for each woman are shown in Fig. 2. Mean (SD) T_{50} was 15 (6.1) min at 37–40 weeks, 11 (5.9) min at 2–3 days postpartum and 15 (5.5) min after the 6-week postnatal assessment (Fig. 3). There was no statistically significant change to T_{50} and retrospective power-analysis (assuming $\alpha = 0.05$ and $\beta = 0.20$) showed that the study was adequate to detect a difference of 8 min.

Discussion

The results of the present study show no significant difference in gastric emptying during the three study periods. Data obtained at 6 weeks postpartum represent the patients' own control value and it is interesting to note that in two patients, T_{50} during pregnancy was twice the control value (Fig. 2). In both these patients, T_{50} decreased within 3 days of delivery. Although gastric emptying during pregnancy was relatively delayed in these patients, it was still within the range of control values obtained for the group as a whole.

The high incidence of inhalation of gastric contents during obstetric anaesthesia over the years has led to much interest in the effects of pregnancy on gastric emptying. Many different techniques have been used, and while some workers have shown delayed emptying during pregnancy, others have found no change. Some of the earlier studies using radiographic techniques failed to show a consistent effect. Hansen [1] demonstrated delayed emptying during pregnancy following a barium meal. However, no change was demonstrated by La Salvia and Steffen [2] using a thin barium meal and by Boyden and Rigler [3] using a fluoroscopic technique.

Using simple dye dilution, Hunt and Murray [8] found no change in gastric emptying in pregnant women when compared with their own control values obtained 40 weeks after delivery. However, Davison and colleagues [9], using a double sampling dye dilution technique, found that emptying of water was delayed compared with nonpregnant controls. APT avoids the use of nasogastric tubes, which are uncomfortable and may affect gastric emptying. In the present study, the women were happy to return for repeat measurements and we had 100% compliance.

Paracetamol absorption has been used during pregnancy to demonstrate delayed gastric emptying [5] or no change [10] compared with nonpregnant control groups. However, the altered pharmacokinetics of paracetamol during pregnancy [4] may render this technique inaccurate.

Epigastric impedance [11] demonstrated no change in gastric emptying during pregnancy but gastric acid secretion was not blocked before the study and this may have affected the results since acid secretion alters gastric impedance. In that study, epigastric impedance was measured using a four electrode system and in 14 out of 68 patients, the area of the stomach was missed. The APT system used in our study utilises 16 electrodes and this enabled us to locate the stomach in all of the patients studied.

APT is well tolerated and provides a useful method of assessing gastric emptying of liquid or solid meals in pregnant patients. The disadvantages of the APT technique is the need for H_2-receptor blockade, but this is of little importance in this study as ranitidine is commonly administered to obstetric patients during labour.

In summary, we have found APT to be an easy, reliable and well tolerated method of assessing gastric emptying in pregnant women. By using women as their own controls, we have shown that there is no consistent change in the rate of gastric emptying in the peripartum period.

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Combined epidural/spinal anaesthesia for Caesarean section

Through the needle or in separate spaces?

G. LYONS, R. MACDONALD AND B. MIKL

Summary

An evaluation of a 30 gauge spinal needle in a combined epidural /spinal anaesthetic technique for Caesarean section revealed a 25% failure rate of the spinal element. In this unit, no more than 4% of spinal anaesthetics might be expected to fail. One of the reasons for the higher failure rate was that, when using the Tuohy needle as an introducer, the dura was not identified. This prompted us to compare the 'through-the-Tuohy' or needle within needle approach for combined epidural/spinal anaesthesia, with a technique that involved siting the epidural and spinal sequentially in separate spaces. One hundred women requiring elective Caesarean section under spinal anaesthesia were randomised into single or double space groups. The technique failed in 16% of through-the-needle cases, and in 4% of sequential sitings. Combined spinal/epidural anaesthesia for Caesarean section is more successful if each procedure is performed using separate spaces.

Key words

Anaesthesia; obstetric.
Anaesthetic techniques, regional; epidural, spinal.

Combined spinal and epidural anaesthesia is advocated for Caesarean section because it is able to ensure anaesthesia, with the option to extend and continue regional blockade, without recourse to subarachnoid catheterisation [1]. However, postdural puncture headache is a major drawback of the technique. Fine spinal needles can significantly reduce the incidence of headache [2,3], but may require an introducer to guide them through the ligaments to the dura. An elegant approach is to use the Tuohy needle in this role [4]. A recent evaluation of a 30 g spinal needle used in this way was associated with unsuccessful spinal anaesthesia in 12 of the 50 patients studied. Six failures were due to unsuccessful dural puncture and six to inadequate block [5].

While some of these difficulties could be attributed to technical problems associated with very fine needles, there was a suspicion that Tuohy-guided dural puncture might be less successful than a separate puncture, which actively seeks cerebrospinal fluid (CSF). In addition, inadequate spread of heavy spinal solution may result if difficulties arise with the placement of the epidural catheter, which follows the removal of the spinal needle from the Tuohy needle. This study is a comparative analysis of the two techniques, with specific reference to efficacy.

Methods

Local Hospital Ethics Committee approval was given for the study and informed consent was obtained from women scheduled for elective Caesarean section who had expressed a desire for the operation to be performed under local anaesthesia. The woman were randomly allocated to receive combined spinal/epidural anaesthesia, either through the Tuohy needle (single space), or by separate punctures (double space). The spinal needles used for the study were both commercially available, 26 gauge (0.45 mm) needles. The length of needle used in the 'single space' group was 88 mm, and that in the 'double space' group was 125 mm.

All women were managed in a similar manner with regard to position during needle insertion and dose of local anaesthetic used. Preloading of the circulation was with polygeline solution up to 1 l. The actual intervertebral space used for the needle insertion(s) was left to the discretion of the anaesthetist as was the relative positions of the Tuohy and spinal needles in the 'double space' group.

The following were recorded for each patient: (1) the number of skin and dural punctures required; (2) the time taken to establish spinal anaesthesia, from gowning to intrathecal injection and from gowning to readiness for surgery; (3) the changes in systolic and diastolic blood pressure from baseline values, at 1, 5, 10, 15 and 20 min after the intrathecal injection; (4) the dose of ephedrine used to treat hypotension; (5) the failure of spinal anaesthesia (a need for an epidural top-up before the birth of the baby was taken to indicate that spinal anaestheisa was inadequate); (6) the segmental rise of block from the site of puncture at 5, 10, 15 and 20 min after intrathecal injection.

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Table 1. Demographic date; mean (SD).

	Single space $n = 50$	Double space $n = 50$
Age; years	27.8 (4.7)	27 (5.1)
Weight; kg	73.4 (13.9)	71.8 (11.2)
Height; m	1.58 (8.4)	1.61 6.7)

Table 2. Times, in minutes, from gowning to intrathecal injection and from gowning to readiness for surgery; mean (SD).

	Single space	Double space	
Gowning to injection	11 (7.4)	14.6 (6.8)	($p < 0.05$)
Gowning to theatre	23 (8.5)	25 (8.3)	NS

Postoperatively the women were questioned about the presence of backache, headache, urinary problems and any delay in mobilisation. Patients were asked to assess the technique in terms of 'good', 'fair' or 'poor', and, if appropriate, to compare it with any earlier experience.

Statistical analysis

This was performed using the Fisher Exact, Chi-squared and Wilcoxon matched pair tests, as appropriate. Significance was assumed at the 5% level ($p < 0.05$).

Results

A total of 100 women were studied. There were no significant differences between the groups with regard to age, weight and height (Table 1).

Intra-operative details

In the 'single space' group, 13 women required an additional skin puncture, either for resiting of the Tuohy needle or for a separate spinal injection. In the 'double space' group where two skin breaches were performed, only one woman required an additional skin puncture. There was a significant difference between the two groups in this respect ($p < 0.01$). However, there was no difference between the groups with regard to the number of dural punctures.

The times taken from gowning to the intrathecal injection and being ready to start surgery are shown in Table 2. The time from gowning to the intrathecal injection was shorter in the 'single space' group (11 versus 14.6 min, $p < 0.05$), but the time from gowning to being ready for surgery was not significantly different for the two groups.

The changes in systolic blood pressure are shown in Figure 1. The systolic blood pressure was lower in the 'single space' group at 15 and 20 min after injection ($p < 0.05$). There was no difference between the groups in systolic blood pressure at any other time, or in diastolic blood pressure at any time. There was no significant difference between the two groups with regard to the dose of ephedrine used to treat hypotention (mean ephedrine dose 11.8 and 8.8 mg for 'single' and 'double' space groups respectively).

A total of 10 spinal anaesthetics were considered to have failed. Eight occurred in the 'single space' group; in four, anaesthesia was provided by the epidural, whilst in the remainder another intrathecal injection was made using a different intervertebral space. All eight subsequently had adequate anaesthesia. In the 'double space' group, two spinal anaesthetics were inadequate, and one of these required a general anaesthetic. There was a significant difference between the two groups with regard to the incidence of failure of adequate spinal anaesthesia ($p < 0.05$).

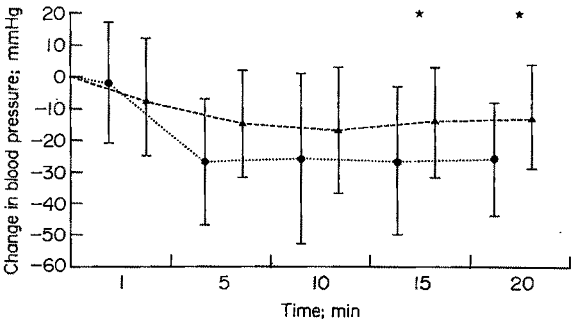

Fig. 1. The change in systolic blood pressure from control value for each group at 1, 5, 10, 15 and 20 min after intrathecal injection; mean and SD. ● single space group, ▲ double space group, * $p < 0.05$.

The 'double space' group developed higher segmental blocks at 10, 15 and 20 min after the intrathecal injection (Fig. 2, $p < 0.05$).

Postoperative complications

There was no difference between the groups in the incidence of headache, backache, urinary problems or delayed mobilisation. One patient in the 'double space' group had a headache sufficient to warrant a blood patch.

Patients' assessment

There was no difference in the patients' assessment of their experiences. Seventeen patients in each group had previously had general anaesthesia for Caesarean section, and most thought spinal anaesthesia better. Nineteen patients in the 'single space' group and 17 in the 'double space' group had previously had epidural anaesthesia for Caesarean section. Of these, two in the 'single space' group, and seven in the 'double space' group thought that spinal anaesthesia was worse. This difference did not reach significance.

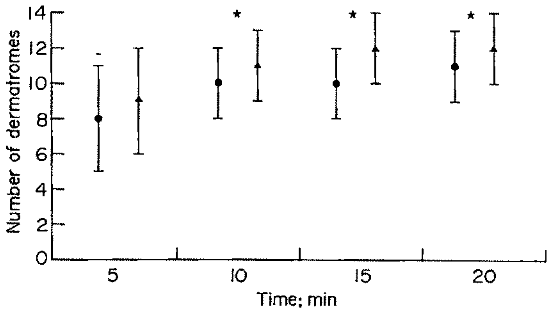

Fig. 2. The segmental rise in block height from the level of intrathecal injection for each group at 5, 10, 15 and 20 min; mean and SD. ● single space groups, ▲ double space group, * $p < 0.05$.

Discussion

Failure of regional anaesthesia has been reported to be in the order of 4% [6,7], but in this study only 1% failed. This was due more to the patient's loss of confidence in the technique than to intractable problems of regional blockade. It would seem therefore that when spinal and epidural anaesthesia are combined, recourse to general anaesthesia becomes a very rare event. One method of combining both techniques described by Rawal *et al.* [8] involves establishing subarachnoid anaesthesia, and then using the epidural for extending the upper end of the block. However, many anaesthetists would regard the epidural as an insurance against unsatisfactory spinal anaesthesia, aiming to provide complete anaesthesia by the subarachnoid route [9]. This investigation deals solely with the practicalities of two different ways of administering spinal anaesthesia.

Spinal anaesthesia through the Tuohy needle has a significantly higher failure rate than when a separate space is sought. Eight 'single space' spinals failed; dural penetration was not possible in three, and was doubtful in a fourth. Inadequate anaesthesia occurred in the other four; only one of these followed difficulty passing the epidural catheter.

Two failures in the 'double spaces' group were due to poor spread; one of these received a general anaesthetic. The other developed unilateral subarachnoid anaesthesia and subsequently a unilateral headache. She required a blood patch.

All grades of staff were involved in the study, but all the failures occurred in the hands of the more experienced. More difficulties occurred with siting epidurals in the 'single space' group, but these were not associated with failure of spinal anaesthesia. This may reflect an awareness of the need to centralise the Tuohy needle to facilitate dural puncture.

The pattern of systolic blood pressure changes followed different courses in the two groups. In general, most 'single space' punctures were carried out at L_{2-3}, while in the 'double space' group, the subarachnoid injections tended to be at L_{3-4}. Despite this the level of anaesthesia tended to be one segment higher in the 'double space' group. By chance, the 'double space' group received, on average, 0.7 mg bupivacaine more than the 'single space' group, but this is of doubtful clinical significance when compared with the different rate of injection down a longer needle, and the slower change in posture while the epidural catheter is fixed. None of these findings reached clinical significance and should not influence choice of technique.

Although statistical significance was not reached, there was a demonstrable lack of enthusiasm for the sequential separate punctures amongst women who had previous experience of regional anaesthesia for Caesarean section. An additional skin breach, while seeming trivial in itself, may have had a greater impact on patient acceptance than we anticipated.

One potential disadvantage of needle through needle techniques is that the epidural catheter may traverse the dural puncture. It is no longer possible to discuss this as a theoretical risk since one such incident has been reported (Russell, personal communication).

Spinal anaesthesia through the Tuohy needle has its advocates [1,4]. We do recognise situations where the technique provides the best option, for example when dealing with the grossly obese. If the technique fails, epidural, or spinal anaesthesia through a separate puncture, remain possibilities. However, increased sophistication in spinal anaesthesia becomes less acceptable if the price is a higher rate of failure.

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Muscle pains and biochemical changes following suxamethonium administration after six pretreatment regimens

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Summary

The incidence of muscle pains and changes in serum concentrations of potassium, calcium and creatine kinase following suxamethonium were investigated after no pretreatment or pretreatment with intravenous tubocurarine 0.05 mg.kg^{-1}*, intravenous chlorpromazine 0.1 mg.kg*$^{-1}$*, alphatocopherol (vitamin E) 600 mg in three divided doses orally, aspirin 600 mg orally or intravenous calcium chloride 5 mg.kg*$^{-1}$ *in groups of 20 patients each. The incidence of myalgia was reduced significantly by tubocurarine, chlorpromazine and alphatocopherol. However, the increase in creatine kinase was attenuated only in the groups of patients who received tubocurarine and chlorpromazine. The changes in serum potassium and calcium concentrations were within acceptable limits. The intubating conditions were not as good in the patients who received tubocurarine as in the other groups. Effectiveness of chlorpromazine in preventing both the myalgia and the biochemical changes suggests the involvement of phospholipases in the pathogenesis of suxamethonium-induced muscle damage.*

Key words

Neuromuscular relaxants; suxamethonium.
Complications; myalgia.

Muscle pains following administration of suxamethonium have been recognised since its introduction into clinical practice [1, 2], and there is often biochemical evidence of muscle damage with raised serum creatine kinase (CK) concentrations in many subjects after its administration [3–5]. The variety of agents which have been employed to reduce the severity of suxamethonium-induced muscle pains and muscle damage underlines our poor understanding of its aetiology [6–12]. It has been suggested that the underlying mechanism of muscle damage associated with administration of suxamethonium may involve calcium-induced phospholipid degradation with release of damaging products of fatty acid metabolism [13]. A similar mechanism has been described by Jackson *et al.* in experimentally induced muscle damage [14]. This is supported by recent experimental work in which chlorpromazine has been shown to inhibit the release of creatine kinase caused by a suxamethonium challenge [15]. The aim of the present study was to examine the effects of a number of pretreatments, which act at neuromuscular or cellular fatty acid metabolic levels, on myalgia and biochemical indices of muscle damage after suxamethonium administration.

Patients and methods

One hundred and twenty patients between the ages of 16 and 65 years and of ASA grade 1 or 2 were included in the study with their informed verbal consent and approval from the University Ethics Committee. All were scheduled to undergo elective ophthalmic surgery which necessitated tracheal intubation, and of an anticipated duration of 45–60 min. This type of surgery was selected because there was minimal risk of surgically induced increases in CK. Patients with peptic ulcer disease, those with known sensitivity to any drugs to be employed in the study, those who were taking any medication known to affect blood electrolyte concentrations or those whose weight deviated by more than 20% from the ideal were not studied. Patients were premedicated with oral diazepam 10–15 mg 90 min before operation. Twenty patients were allocated randomly to each of six groups: group 1, control group, no pretreatment; group 2, tubocurarine 0.05 mg.kg^{-1} intravenously 3 min before induction of anaesthesia; group 3, chlorpromazine 0.1 mg.kg^{-1} intravenously 3 min before induction of anaesthesia; group 4, alphatocopherol acetate

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Table 1. Grading system for postoperative myalgia (after White [16]).

Nil	No pain
Slight	Pain at one site but not causing disability
Moderate	Pain at more than one site but not causing disability
Severe	Pain at more than one site and causing disability, e.g. difficulty getting out of bed, turning head, etc.

(vitamin E) 200 mg orally 6-hourly pre-operatively for three doses; group 5, soluble aspirin 600 mg orally 1 h pre-operatively; group 6, calcium chloride 5 mg.kg^{-1} intravenously 3 min before induction of anaesthesia.

An intravenous cannula was inserted into a large vein in the forearm or antecubital fossa on arrival in the anaesthetic room and a 5 ml blood sample was withdrawn without stasis for analysis of baseline potassium (K$^+$), calcium (Ca^{++}) and creatine kinase (CK) concentrations. A separate vein in the other arm was cannulated for administration of anaesthetic agents and intravenous fluids. The electrocardiogram, indirect arterial pressure, peripheral oxygen saturation and neuromuscular block (using a Myotest) were monitored routinely in all patients. Anaesthesia was induced with thiopentone 4–5 mg.kg^{-1} intravenously followed by suxamethonium 1.5 mg.kg^{-1} when consciousness was lost. Tracheal intubation was performed 1 min later. Anaesthesia was maintained with 66% nitrous oxide in oxygen and isoflurane 1–2%. If required, a nondepolarising muscle relaxant was administered when the effect of suxamethonium had worn off. All analgesic or antiemetic medication was administered intravenously or orally for the first 24 h.

Assessment was made of intubating conditions by an anaesthetist who was unaware of the patient's pretreatment. The conditions were graded on a three-point scale as 'poor', 'adequate' or 'good', taking into account the masseter muscle tone and vocal cord relaxation. Additional blood samples were withdrawn for further electrolyte analyses 1, 3 and 5 min after administration of suxamethonium.

Patients were visited 24 and 48 h postoperatively by one of the authors who was blinded to the identity of the pretreatment group, and the presence and severity of myalgia were noted. Myalgia was graded on a four-point scale as 'nil', 'slight', 'moderate' or 'severe' using the grading system described by White [16] and shown in Table 1. A further blood sample was withdrawn for CK analysis at the 24-h visit. Total calcium concentrations were corrected to an albumin concentration of 40 g.l^{-1}.

Changes in CK from time 0 to 24 h, and changes in K$^+$ and Ca^{++} concentrations, were analysed by one-factor analysis of variance (ANOVA). Myalgia and intubating conditions were analysed using Kruskal–Wallis and Mann–Whitney *U* tests. A p value of < 0.05 was considered significant.

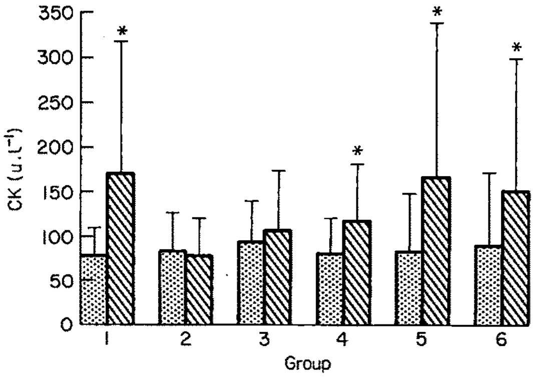

Fig. 1. Creatine kinase (CK) concentration before and 24 h after administration of suxamethonium. Bars represent SD. ▒, baseline; ▧, 24 h. *$p < 0.05$ in comparison to the respective baseline value. Groups: 1 = control group, 2 = tubocurarine, 3 = chlorpromazine, 4 = alphatocopherol, 5 = aspirin, 6 = calcium chloride.

Results

The six groups were comparable with regard to age, weight and sex distribution (Table 2).

The mean CK concentrations before induction of anaesthesia and at 24 h postoperatively are shown in Figure 1. The baseline CK concentrations were not significantly different among the groups and ranged from 78 to 94 u.l^{-1} (normal laboratory values 30–140 u.l^{-1}). CK increased in the control group (group 1) by a mean of 93 u.l^{-1}, which was statistically significant ($p < 0.05$). There were small and statistically insignificant changes in CK in patients who had received tubocurarine (-5 u.l^{-1}) or chlorpromazine (13 u.l^{-1}) before suxamethonium. The mean increase in CK in patients who received alphatocopheral was 37 u.l^{-1}, which was a significant increase from baseline value in this group. CK increases in the aspirin and calcium pretreatment groups of 85 and 62 u.l^{-1} respectively were significant and similar in magnitude to those in the control group.

The average K$^+$ and total Ca^{++} concentrations before and after administration of suxamethonium are shown in Tables 3 and 4 respectively. The changes in these concentrations were small and in general statistically insignificant, with the exception of group 6 (calcium pretreatment) where the total Ca^{++} levels were significantly elevated ($p < 0.05$).

The incidence of myalgia in each group is shown in Figure 2. Fifty-five per cent of patients in the untreated group suffered some myalgia compared with 15% in the patients who received tubocurarine or chlorpromazine, and 10% in those who received alphatocopherol. The incidences and severity of myalgia were significantly lower in

Table 2. Anthropomorphic data for patients in the six groups. Data are presented as mean (SD).

Group	1	2	3	4	5	6
Age; years	48 (15)	46 (18)	48 (16)	42 (19)	47 (17)	46 (11)
Weight; kg	73 (15)	71 (12)	69 (12)	66 (14)	72 (10)	69 (12)
Sex; M/F	13/7	14/6	12/8	12/8	13/7	12/8

Groups: 1 = control group, 2 = tubocurarine, 3 = chlorpromazine, 4 = alphatocopherol, 5 = aspirin, 6 = calcium chloride.

Table 3. Mean (SD) serum potassium concentration (mmol.l^{-1}) after administration of suxamethonium.

Time	0	1 min	3 min	5 min
Group 1	4.1 (0.3)	4.0 (0.3)	4.1 (0.4)	4.1 (0.4)
Group 2	4.2 (0.4)	4.1 (0.4)	4.2 (0.3)	4.2 (0.3)
Group 3	4.3 (0.3)	4.2 (0.3)	4.2 (0.4)	4.1 (0.4)
Group 4	4.2 (0.4)	4.1 (0.3)	4.3 (0.3)	4.3 (0.4)
Group 5	4.2 (0.4)	4.1 (0.5)	4.2 (0.6)	4.3 (0.7)
Group 6	4.0 (0.4)	4.0 (0.4)	4.0 (0.4)	3.9 (0.4)

Groups: 1 = control group, 2 = tubocurarine, 3 = chlorpromazine, 4 = alphatocopherol, 5 = aspirin, 6 = calcium chloride.

Table 4. Mean (SD) total serum calcium concentration (mmol.l^{-1}) after administration of suxamethonium.

Time	0	1 min	3 min	5 min
Group 1	2.25 (0.07)	2.23 (0.08)	2.24 (0.06)	2.24 (0.07)
Group 2	2.21 (0.09)	2.20 (0.09)	2.20 (0.08)	2.19 (0.08)
Group 3	2.22 (0.08)	2.20 (0.08)	2.22 (0.07)	2.22 (0.07)
Group 4	2.19 (0.08)	2.18 (0.08)	2.18 (0.08)	2.18 (0.07)
Group 5	2.20 (0.07)	2.20 (0.09)	2.21 (0.08)	2.19 (0.08)
Group 6	2.21 (0.10)	2.64 (0.11)*	2.58 (0.09)*	2.53 (0.10)*

Groups: 1 = control group, 2 = tubocurarine, 3 = chlorpromazine, 4 = alphatocopherol, 5 = aspirin, 6 = calcium chloride. *$p < 0.05$ in comparison to time 0.

these three groups than in the control group. Although ranked pain scores were lower in the aspirin than the untreated group the result failed to achieve statistical significance ($0.1 > p > 0.5$). Calcium pretreatment was associated with an incidence of myalgia of 25%, which was not significantly different from the control group.

Intubating conditions (Fig. 3) were similar and generally good or adequate in all groups except group 2 (tubocurarine).

Discussion

The use of small doses of nondepolarising muscle relaxants, and in particular tubocurarine, as pretreatment, has been considered almost a 'gold standard' in the prevention of suxamethonium-induced myalgia and muscle damage. In the present study, both the incidence of myalgia in untreated patients and the reduction in its incidence by pretreatment by tubocurarine were comparable to values reported by other workers [11, 16, 17]. However, tubocurarine interferes with the neuromuscular blocking action of suxamethonium and the otherwise excellent intubating conditions that it provides [12].

The present study examined the efficacy of agents which do not act at the neuromuscular junction in attenuating both the myalgia and the biochemical damage caused by suxamethonium but without interfering with its desirable neuromuscular blocking effects. That these agents did not interfere with the neuromuscular blocking effect of suxamethonium is shown indirectly by the observation that there was no difference in the intubating conditions in the groups of patients who received these agents compared with those in the control group.

A number of investigators have stressed the importance of an increase in myoplasmic calcium concentrations in initiating muscle damage in a variety of situations [18–20]. The suggested mechanism involves activation of phospholipase A2 (PLA2), which produces membrane phospholipid degradation and releases lysophospholipids and free fatty acids. It has been proposed that arachidonic acid metabolites, particularly of the lipoxygenase pathways, may be involved in damage which leads to cellular enzyme release

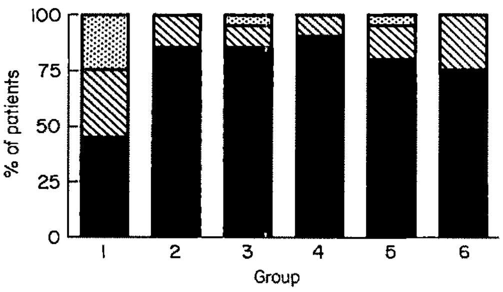

Fig. 2. Incidence of myalgia. ■, nil; ▨, slight; ▩, moderate (no patient suffered severe myalgia). Groups: 1 = control group, 2 = tubocurarine, 3 = chlorpromazine, 4 = alphatocopherol, 5 = aspirin, 6 = calcium chloride.

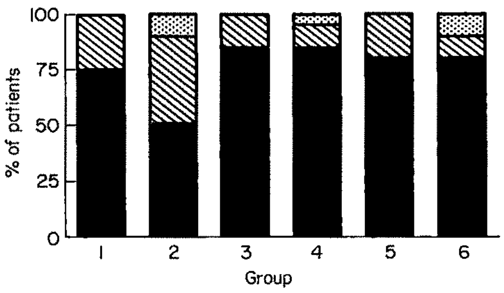

Fig. 3. Intubating conditions. ■, good; ▨, adequate; □, poor. Groups: 1 = control group, 2 = tubocurarine, 3 = chlorpromazine, 4 = alphatocopherol, 5 = aspirin, 6 = calcium chloride.

[14, 21]. In addition, free radical species may be involved in this process as it is known that vitamin E deficient muscles are more susceptible to damage [22]. There is evidence from *in vitro* experiments that PLA2 and lipoxygenase inhibition may have a therapeutic role in attenuating this damage [20, 23]. Recent work with an isolated muscle preparation has shown that chlorpromazine in a concentration known to inhibit PLA2 was able to inhibit suxamethonium-induced CK efflux [15]. In the present study, pretreatment with tubocurarine was the most effective method of preventing the rise in CK but at the expense of poorer intubating conditions, presumably by interference with the neuromuscular effects of suxamethonium. As its predominant action is presumably at the neuromuscular junction it does not help our understanding of the effects of suxamethonium on the myoplasmic environment. Chlorpromazine obtunded the rise in CK, and this may be related to its ability to inhibit cellular phospholipases, specifically PLA2, which is known to be activated by increased myoplasmic Ca^{++} concentrations [21]. In the present study and in the dose employed, it was not associated with any cardiovascular side effects or obvious sedation.

Pretreatment with aspirin reduced the incidence of myalgia but did not prevent CK release. Lack of a good correlation between myalgia and enzyme elevation has also been reported by other workers [24]. This underlines the difficulty in defining a single measure of muscle damage and it is likely that myofibrillar disruption and pain arise by different processes. The possibility that separate mechanisms may be involved is supported also by the observation that whereas alphatocopherol significantly reduced myalgia, its effect on obtunding the rise in CK was less marked. This finding supports the contention that metabolism of arachidonic acid via the cyclo-oxygenase pathway may be less important than lipoxygenase pathways in the process of cellular damage [14].

Calcium chloride was only partly successful in reducing the incidence of myalgia, a finding which contrasts with that reported by Shrivastava *et al.* [10] who found an incidence of only 2% following pretreatment with calcium; however, a larger dose of calcium was employed than in our study. It was an interesting finding that the increased serum calcium concentration did not lead to increased CK release. If, as has been speculated, enzyme release is related to calcium influx into the myoplasm then raising plasma concentrations of the ion might have been expected to increase this influx. However, unlike cardiac muscle, skeletal muscle is less influenced by extracellular calcium concentrations and cellular levels are more dependent on calcium release from the sarcoplasmic reticulum [25].

In summary, this study confirms that subjective muscle pain and cellular enzyme release, which together with histological changes constitute 'muscle damage', are separate entities. Chlorpromazine and alphatocopherol acetate, which are known to influence cellular fatty acid metabolism, reduce either muscle pain and/or enzyme release, which supports the suggestion that suxamethonium-induced muscle damage may involve these pathways. They may form alternative approaches to preventing some of the side effects of suxamethonium, especially when it is essential to preserve the quality of neuromuscular blockade. More direct studies of measurement of neuromuscular blockade after these pretreatments are necessary to confirm lack of neuromuscular effects.

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Two approaches to the axillary brachial plexus

Loss of resistance to saline or paraesthesia?

D. A. HILL AND W. I. CAMPBELL

Summary

A new technique of cannulation of the axillary neurovascular sheath, using loss of resistance to saline, was evaluated and compared to the established technique of eliciting paraesthesiae with a short-bevelled needle. The cannulation technique produced a more reliable block of axillary, musculocutaneous and radial nerves, significantly fewer incomplete blocks and a lower incidence of accidental vessel puncture.

Key words

Anaesthetic techniques, regional; brachial plexus block.

The axillary brachial plexus block is a safe and straightforward method of anaesthetising the arm. It is very suitable for day patients, with no risk of pneumothorax. Success depends on injection of local anaesthetic within the neurovascular sheath. Commonly, this is identified by eliciting paraesthesiae [1] with a short-bevelled needle [2].

The risks of neural [3] and vascular complications have led to the use of a cannulation technique by eliciting a 'click' [4] or by 'railroading' a catheter into the sheath over a flexible guide wire [5]. However, these techniques are not always easy to perform.

This study was designed to evaluate a new method of sheath cannulation using 'loss of resistance to saline' and to assess the effectiveness of a block established in this way in comparison to a block in which the correct position of a short-bevelled needle was determined by eliciting paraesthesiae.

Patients and methods

Sixty patients, aged between 18 and 60 years and scheduled to undergo upper limb surgery were studied. All patients gave verbal consent for the study, which was approved by the Research Ethics Committee of Queen's University, Belfast.

The patients were allocated randomly to one of two groups. Patients in group A received an axillary brachial plexus block after paraesthesiae were elicited with a short-bevelled needle; in group B, a cannula was inserted perivascularly using loss-of-resistance to saline (see below).

None of the patients was premedicated. On arrival in the anaesthetic room, an indwelling cannula was placed in a vein in the arm which did not require surgery. The other arm was abducted to 90°, with the hand resting on a pillow next to the patient's head. The axillary artery was identified as far proximally as possible.

Group A

An extension set primed with local anaesthetic was connected to the short-bevelled needle. The index finger of one of the operator's hands was pressed over the artery as near to the anterior axillary folds as possible, and a 22-gauge regional block needle (Becton Dickinson short bevel) was inserted immediately above the finger at an angle of 20° to the skin. It was directed parallel and just next to the artery. The needle was advanced slowly and its position adjusted until paraesthesiae in the hand were elicited. Aspiration was performed continuously by an assistant so that inadvertent vessel puncture was identified and corrected. Thirty-five millilitres of lignocaine 1.5% with 1:200 000 adrenaline were injected over a period of one minute. As soon as the injection was completed, the needle was withdrawn and the arm brought down by the patient's side. A tourniquet was inflated to 160 mmHg for 5 min.

Group B

A 10 ml syringe, filled with sterile normal saline, was connected to a 20-gauge × 51 mm intravenous cannula (Insyte). The index and middle fingers of one hand were pressed over the artery as near to the anterior axillary fold as possible. The cannula connected to the 10 ml syringe of saline was inserted below the index finger at an angle of 20°

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to the skin. It was directed parallel and next to the artery. Continuous pressure was placed on the plunger of the syringe which advanced the cannula until a loss of resistance was demonstrated by easy injection of saline. Aspiration was performed to exclude vascular placement. The cannula was advanced off its introducer until fully inserted. Thirty-five millilitres of lignocaine 1.5% with 1:200000 adrenaline were injected over a period of one minute, with aspiration tests every 5 ml. On completion of injection the arm was brought down by the patient's side. A tourniquet was inflated to 160 mmHg for 5 min.

All blocks were performed by one of the authors and then assessed by one of two independent observers who did not know the technique used. The sensory changes were assessed 30 min after the injection using a 25-gauge needle. Sensory testing was carried out in areas supplied by the following nerves: axillary, musculocutaneous, radial, median, ulnar, medial cutaneous nerve of arm, medial cutaneous nerve of forearm.

A successful block, as described by Vester-Anderson *et al.* [1] was classified as either complete, if there was loss of sensation in areas supplied by all cutaneous nerves peripheral to the axillary nerve, or incomplete. A failed block was one in which the sensory blockade involved only a single nerve or none of the following nerves: median, ulnar, radial, musculocutaneous.

The area supplied by the ulnar nerve was tested at 5-min intervals and the onset of blockade recorded. If the artery was punctured inadvertently, this was noted.

Student's *t*-test was used to compare the mean age, weight and height of the patients. The Chi-square test was used to compare the failure rate, vessel puncture rate, and frequency of blocked nerves. Wilcoxon rank sum test was used to analyse the ulnar onset times. A p value of < 0.05 was accepted as significant.

Results

The mean age, weight and height of the 30 patients in each of the two groups were comparable (Table 1). The results of axillary brachial plexus anaesthesia in each group are shown in Table 2. The incidence of complete blocks was significantly less in group A than group B. The block failed totally in 7% of patients in each group.

Table 1. Characteristics of patients, Data are presented as mean (SD).

	Group A	Group B
Age; years	30.1 (13.3)	32.3 (14.7)
Weight; kg	69.4 (8.5)	58.2 (8.9)
Height; cm	170.3 (5.6)	168.5 (6.4)

Table 2. Effectiveness of blocks.

	Group A, $n = 30$	Group B, $n = 30$
Complete block	13 (43%)	22 (73%)*
Incomplete block	15 (50%)	6 (20%)*
Total failure	2 (7%)	2 (7%)

*p < 0.05.

Table 3. Frequency of nerve block.

Nerve	Group A, $n = 30$	Group B, $n = 30$
Axillary	15 (50%)	25 (83%)*
Musculocutaneous	16 (53%)	25 (83%)*
Radial	18 (60%)	25 (86%)*
Median	28 (93%)	27 (90%)
Ulnar	29 (96%)	30 (100%)
Med. cut. n. of forearm	21 (70%)	26 (86%)
Med. cut. n. of arm	22 (73%)	25 (83%)

*p < 0.05.

Table 4. Number of patients who required supplementation of axillary block to allow surgery.

	Group A $n = 30$	Group B $n = 30$
General anaesthetic	4 (14%)	2 (7%)
Additional nerve block	5 (17%)	2 (7%)

Table 3 shows the distribution of nerve block associated with each approach. There were statistically significant differences in the incidences of successful block of the axillary, musculocutaneous and radial nerves.

Four patients in group A received general anaesthesia because of a failed or incomplete block; five other patients required a supplementary peripheral nerve block (Table 4). Two patients in group B required general anaesthesia for failed block and two required supplementation for incomplete block (5 ml of lignocaine 2% plain). These differences were not statistically significant.

The ulnar nerve onset time was significantly shorter in group B (Fig. 1). The incidence of vessel puncture in group B (7%) was significantly less than that in group A (33%).

Discussion

This study demonstrates that there was no significant advantage of one technique over the other in relation to total failure (7%). This overall success rate is comparable to those reported in other studies [6, 7]. However, there was a significantly greater number of complete blocks in group B than in group A. The main causes of unsuccessful block are total failure because of unintentional injection outside the neurovascular sheath and incomplete block in spite of correct injection [1]. Our results suggest that both techniques are equally successful at identifying the neurovascular sheath, but that cannula insertion gives a better distribution of block.

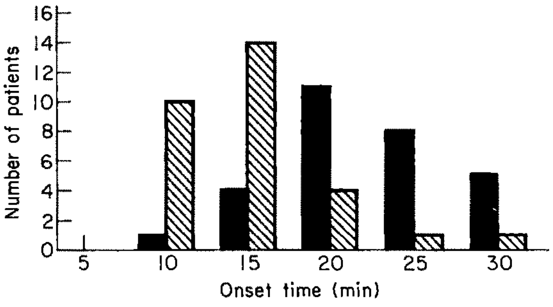

Fig. 1. Distribution of onset times to blockade of the ulnar nerve ■, group A; ▨, group B.

Various theories have been proposed to explain the variable distribution of block. Thomson and Rorie [8] demonstrated septa around each nerve which they believed might limit circumferential spread of local anaesthetic, and recommended multiple small-volume injections. Vester-Anderson *et al.* [9] were unable to demonstrate septa on cadavers, but found that as the arm was abducted the stretched neurovascular bundle approached the lateral wall of the axilla, limiting spread of local anaesthetic to the radial, musculocutaneous and axillary nerves. They concluded that this physical restriction of injected solution was responsible for incomplete blocks. Partridge *et al.* [10] demonstrated incomplete 'velamentous' septa which did not significantly affect the spread of local anaesthetic and found multiple injections unnecessary. Ang *et al.* [6] found that injection outside the sheath could still produce a block, although delayed.

The significantly better quality of block of the axillary, musculocutaneous and radial nerves in group B in this study shows that the cannula is able to overcome these restrictions in spread of local anaesthetic compared to the use of a short-bevelled needle. The proximally directed injection via a cannula may explain this. Selander *et al.* [4] inserted cannulae using the 'snap or click' method to obtain a complete block rate of 63%. Ang *et al.* [6] inserted 80 mm catheters (using perivascular pulsation of a 19-gauge needle to identify the sheath) and claimed a 98% success rate.

The significantly shorter ulnar onset time in group B is difficult to explain, but suggests that the local anaesthetic is being delivered closer to the nerves than occurs when a short-bevelled needle is employed. The higher incidence of vessel puncture in the short-bevelled needle group may delay onset time.

Complications of axillary block are relatively low. However, it has been shown that eliciting paraesthesiae is associated with a 2.8% incidence of nerve damage [3]. Moore *et al.* [11] suggested 'no paraesthesia, no anaesthesia' and eliciting of paraesthesiae is regarded by many anaesthetists as essential. This study shows that there is no advantage in eliciting paraesthesiae, especially when multiple attempts are often necessary for its demonstration. Haematoma formation [12], vascular spasm [13] and inadvertent intravascular injection [11] are all well recognised. The transarterial techniques [14] are more likely to result in these complications. In this study, a significantly lower incidence of vessel puncture occurred in group B (7% vs. 33%). The loss of resistance technique not only identifies the neurovascular sheath but warns of impending vessel puncture if the introducing needle of the cannula is advanced.

In conclusion, this new technique of axillary block is reliable and safe when compared to the commonly used short-bevelled needle technique. Damage to nerves or vessels is less likely. The cannula itself provides several advantages: the facility for protracted analgesia by infusion or repeated injection, the opportunity to top up an inadequate block, and the ability to make the injection with the arm by the patient's side. This relaxes the sheath [9] and avoids compression by the humeral head, so promoting better proximal spread [15]. Furthermore, the block can be established safely in anaesthetised patients for intra-operative and postoperative analgesia.

Acknowledgments

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Appropriate use of local anaesthetic for venous cannulation

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Summary

A departmental survey indicated that the large majority of anaesthetists believed that injection of local anaesthetic before insertion of an intravenous cannula was unnecessary if a cannula of 18 gauge or smaller was used, because injection of local anaesthetic would be more painful than insertion of the cannula. A study was undertaken to test this hypothesis. The results showed that intravenous cannulation with a cannula of 18, 20 or 22 gauge was significantly ($p < 0.006$) more painful than a subcutaneous injection of 1% lignocaine. We recommend that subcutaneous injection of local anaesthetic should be considered before insertion of any size of intravenous cannula.

Key words

Veins; cannulation.
Anaesthetics, local; lignocaine.

It is common practice amongst anaesthetists to inject subcutaneous lignocaine 1% before insertion of a large intravenous cannula in adults. However, a survey in our anaesthetic department revealed that there was no unanimous opinion as to the smallest size for which the pain of insertion of a cannula was outweighed by the pain caused by the prior injection of local anaesthetic. Eighty-eight per cent of anaesthetists in our department used local anaesthetic before inserting a cannula of 16 gauge or larger, but only a small proportion used local anaesthetic before insertion of a cannula of 18 gauge or smaller in adults. The principal reason given for this practice was that insertion of a small cannula is not painful, and that the pain of injecting local anaesthetic exceeds the pain of insertion of the cannula.

Consequently, a study was undertaken to assess the validity of this opinion, and to establish which size of intravenous cannula, in the opinion of the patient, warranted the prior subcutaneous injection of subcutaneous lignocaine 1%.

Patients and methods

The study was approved by the District Ethics Committee and written informed consent was obtained from all participants. Sixty adult patients, who were about to undergo surgery under general anaesthesia, were included in the trial. Each patient was allocated randomly into one of three groups, to receive intravenous cannulation with a Venflon cannula of 18 (group 1), 20 (group 2) or 22 gauge (group 3). Random allocation was achieved by taking a prewritten card, blind, from a bag, such that 20 patients entered each group. Within each group, the side of cannulation (left or right) and the order of cannulation (before or after subcutaneous injection of lignocaine) was randomised equally within groups by the same method. Patients were premedicated or not as determined by the anaesthetist.

The patient's eyes were closed throughout the procedure and a tourniquet was applied to both arms. A subcutaneous injection of 0.25 ml of lignocaine 1% through a 25 gauge needle was given into the dorsum of one hand and a Venflon of predetermined size was inserted into the corresponding site in the other hand (or vice versa depending on randomisation).

The patients were then asked which was the more painful, and graded each insertion on a discrete pain scale of 1 to 10 (1: no pain; 10: worst pain imaginable). All cannulations were successful at the first attempt. Results were analysed using the Wilcoxon signed rank test and the Mann–Whitney U test.

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Results

Sixty patients completed the trial: 19 were male. Age ranged from 19 to 79 years (mean 40 years). One patient in group 1 (18 gauge) found the local anaesthetic injection more painful than venous cannulation; the median pain scores were 8 and 2 for cannulation and local anaesthetic injection respectively. In group 2 (20 gauge), all patients found venous cannulation more painful than local anaesthetic injection; median pain scores were 6 and 1 for cannulation and local anaesthetic injection respectively. Three patients in group 3 (22 gauge) found the local anaesthetic injection more painful than intravenous cannulation; median pain scores were 5 and 1 for cannulation and local anaesthetic infiltration respectively. The distribution of pain scores in the three groups is shown in Figure 1.

The differences between pain scores for cannulation and local anaesthetic injection were analysed using the Wilcoxon signed rank test. Venous cannulation was significantly more painful than local anaesthetic injection in all three groups (groups 1 and 2, $p < 0.001$; group 3, $p < 0.006$).

The Mann–Whitney *U* test was used to analyse differences in the pain scores among the three sizes of intravenous cannula. There was a significant difference in pain scores between 18 gauge and 22 gauge ($p < 0.0007$) and 20 gauge and 22 gauge cannulae ($p < 0.03$) but no significant difference in pain scores between 18 gauge and 20 gauge cannulae.

Discussion

Pain and anxiety can result from venous cannulation prior to induction of anaesthesia. Various methods have been employed to alleviate this suffering, including ethyl chloride spray, intradermal or subcutaneous injection of lignocaine, prior application of EMLA cream and distraction techniques. A recent study by Armstrong *et al.* [1] has shown that the use of ethyl chloride spray or intradermal lignocaine decreases the pain associated with insertion of a 20 gauge intravenous cannula.

Studies in children [2–4] indicate that EMLA cream reduces the pain of intravenous cannulation even with the smallest of cannula sizes. EMLA cream is rarely used in adults because of its expense, the need for application approximately 2 h before cannulation, and the common belief that insertion of a small intravenous cannula is not painful.

There has been little investigation of the use of local anaesthesia before intravenous cannulation in adults. We elected to use subcutaneous lignocaine as it is cheap, in

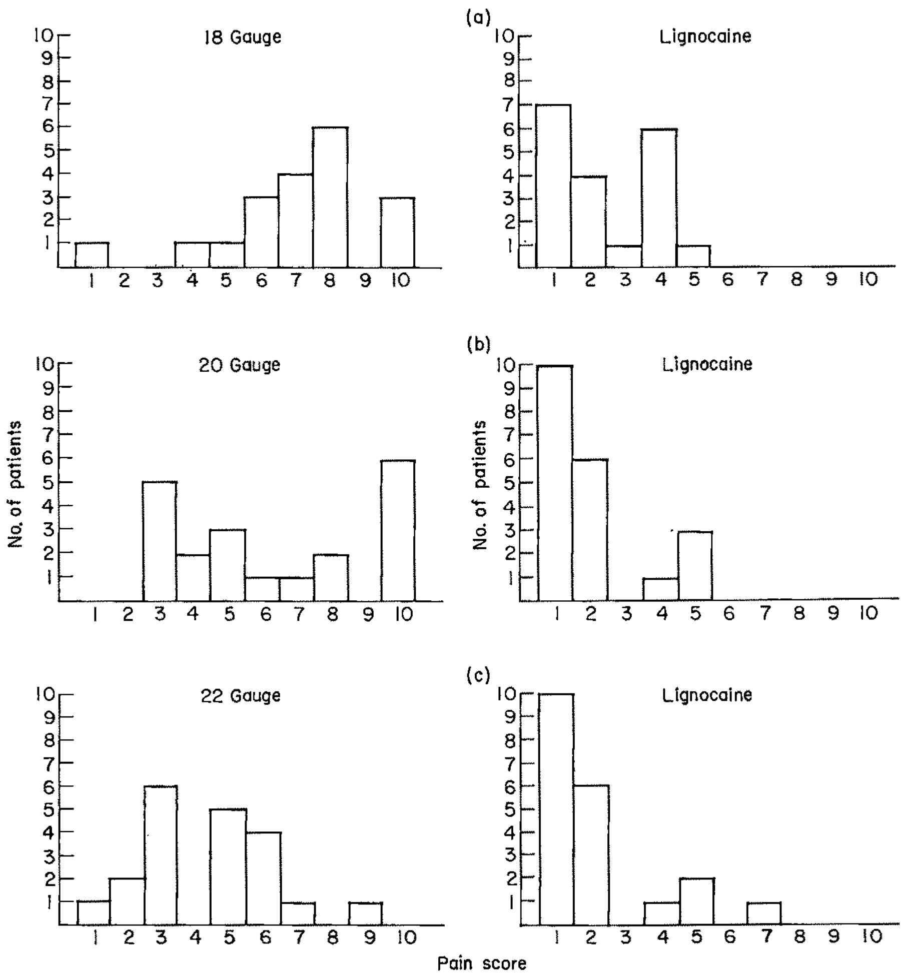

Fig. 1. Distributions of pain scores in patients in whom an intravenous cannula of 18 gauge (a), 20 gauge (b) or 22 gauge (c) was inserted into the dorsum of one hand, and 0.25 ml lignocaine 1% into the corresponding site in the other hand.

common use, and can be administered immediately before cannulation. It is argued that local anaesthesia by this method makes cannulation more difficult as swelling from the injection obscures the vein; this is easily remedied by compression over the site of injection. The other drawback of this technique is that accidental venous puncture may occur, increasing peri-operative morbidity due to bruising, pain and the need to find a new injection site. These hazards can be minimised by careful location of the site of injection and operator skill.

Our results show that the reasons given by anaesthetists in our department for not using local anaesthesia prior to intravenous cannulation with a small cannula are invalid. Our study indicates that a subcutaneous injection of local anaesthetic is of significant benefit prior to insertion of intravenous cannulae as small as 22 gauge. We would further suggest that there is no advantage (except in cases where only very small veins are visible) in using a small cannula if local anaesthesia is always used, as a larger cannula (18 gauge or greater) affords greater safety to the patient if some form of resuscitation becomes necessary.

Acknowledgments

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Hoarseness after tracheal intubation

M. W. JONES, S. CATLING, E. EVANS, D. H. GREEN AND J. R. GREEN

Summary

The reported incidence of hoarseness following short-term tracheal intubation varies widely. It has been reported as being permanent in 3%. This suggests that an enormous problem exists considering the numbers of patients intubated daily in the United Kingdom. A prospective study of 235 adult patients undergoing general anaesthesia in a district general hospital included 167 patients whose tracheas were intubated. Of these 167, 54 (32%) complained of hoarseness postoperatively. All but five returned to normal within 7 days. The others were hoarse for 9, 10, 12, 54 and 99 days. Those who were hoarse for 54 and 99 days had vocal cord granulomata. Regression analyses showed that certain patient and anaesthetic factors had a significant effect on the hoarseness. This study confirms a low incidence of prolonged or permanent hoarseness following short-term tracheal intubation.

Key words

Intubation tracheal; complications, hoarseness.

There is a large variation in the reported incidence of hoarseness immediately following short-term tracheal intubation. It occurs in between 4 and 42% of patients [1–5] and may be a long-term problem in less than 1% [2,6], but one series reported that 3% of women undergoing mastectomy had voice changes at the end of 6 months [3]. If this latter figure is representative of British practice in general, an enormous problem exists when the number of patients intubated daily in the United Kingdom is taken into account.

The aims of this prospective study were to determine the incidence and severity of hoarseness following short-term intubation in a variety of patients in a district general hospital and to identify risk factors.

Methods

Two hundred and thirty-five consecutive patients undergoing a variety of elective and emergency surgical procedures in a district general hospital were studied. There were 145 women and 90 men. Their ages ranged from 17–85 years and their weight from 45–116 kg (mean 66.5, SD 11.9). Patients who had undergone previous head and neck surgery, or who were about to do so or had previous voice problems were not studied.

All patients had their voices recorded whilst reciting a standard text before operation. No attempt was made to influence the anaesthetic techniques used, which were selected by anaesthetists of varying seniority according to the type of surgery undertaken. Factors thought likely to influence the larynx were recorded and are shown in Table 1.

After surgery, all patients had their voices recorded and were asked by either M.W.J. or S.C. 24 h later if they thought they were hoarse or not (as distinct from having a sore throat) and whether this was mild or severe. Further subjective assessments were made by further personal visits to assess hoarseness until the patients stated that the voice was normal. This duration was noted and their voice was recorded again. The recordings were anlaysed in two ways.

First, the speech therapist compared the pre-operative recording with the 24 h postoperative recording, without being aware of whether or not the patient complained of hoarseness. The voice was scored using a 100 mm visual analogue scale, with 0 indicating they were not hoarse and 100 showing severe hoarseness. Similarly, the recording at the time of full recovery was scored.

Second, waveforms of all tape recordings were made using a Visi-Pitch 6087DS oscilloscope (Kay Elemetrics Corp., 12 Maple Avenue, Pine Brooks, New Jersey 07058-

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Table 1. Patient and anaesthetic factors thought likely to affect the larynx.

Age
Sex
Weight
Number of cigarettes smoked daily
Use of pharyngeal drying agent with premedication
Induction agent used (thiopentone, methohexitone, etomidate, diazepam, midazolam, ketamine)
Dose of induction agent used
Tracheal intubation used or not
Type of tube used (red rubber, Portex theatre tubes, Rae and Mallinckrodt long reinforced PVC orotracheal tubes with standard cuffs, armoured latex, Vygon, Searle, other)
Size of tracheal tube used
Amount of air in tracheal tube cuff
Type of tube lubricant used (none, KY jelly, lignocaine gel)
Local anaesthetic spray to vocal cords used or not
Intubating conditions (easy, difficult or very difficult)
Introducer used or not
State of vocal cords at intubation (wide open, moving, closed, not seen)
Muscle relaxant used (none, suxamethonium, curare, alcuronium, vercuronium, atracurium, pancuronium, gallamine)
Dose of muscle relaxant used
Duration of anaesthesia
Grade of intubator (consultant, senior registrar, registrar, SHO, student, nurse)
Pharyngeal suction used or not

9797, USA and Wessex Electronics, 114-116 North Street, Downend, Bristol BS16 5SE). Changes between the pre-operative and the 24 h postoperative waveforms were scored by one observer (S.C.), who was unaware of whether the patient complained of hoarseness, on a scale from 1 (no change) to 5 (severe change). The recording at the time of full recovery was also scored, after comparison with the pre-operative recording. Due to the nature of this subjective assessment, it was not possible to score each recording blindly since the score was based on a change in waveform. In appropriate cases, further follow-up and treatment was necessary. The factors used in the post-operative assessment of the larynx are shown in Table 2.

Results

We found a highly significant and positive correlation between the patients' subjective assessment of their hoarseness and both the scores of the speech therapist and the Visi-Pitch recordings. Tracheal intubation resulted in significant hoarseness ($p < 0.001$ using Chi-squared) in the 167 (71%) patients whose tracheas were intubated when compared to the 68% (29%) patients who were not. Four (6%) of those not intubated complained of mild hoarseness, which lasted 2 days in three patients and 4 days in one. Of those intubated, 54 (32%) complained of temporary hoarseness, but there were no permanent voice changes. These data are analysed in Table 3. The hoarseness lasted less than a week in most patients and if the five patients who were hoarse for more than a week are excluded, the mean duration of hoarseness was 3.4 days (SD 1.7). Three patients were referred for indirect laryngoscopy after remaining hoarse for 99, 54 and 9 days. The latter patient had a normal larynx. The other two had granulomata of the vocal chords. The patient who had been hoarse for 99 days was given speech therapy and the other treated by resting the voice. All made a full recovery.

Table 2. Factors used to assess the larynx postoperatively.

At 24 hours
Patient's assessment of hoarseness (none, mild, severe)
Speech therapist score (0 (not hoarse) 100 (severe hoarseness))
Visi-Pitch score (0, no change—5, severe change)
At full recovery
Time to full recovery (days)
Speech therapist score (0, not hoarse—100, severe hoarseness)
Visi-Pitch score (0, no change—5, severe change)
Laryngoscopic findings
Not referred, normal haematoma, granuloma, cord paralysis

In an attempt to define the factors contributing to the hoarseness, regression analyses were used. Some of the variables had to be removed to avoid singularities in the regressions or because they were too sparsely represented to be included. For example, of the 235 cases, there were either none or very few that used certain induction agents (etomidate, diazepam, midazolam). Even some included variables were later found to have very few nonzero values. In addition, there were certain dependent variables, related to the patient's follow-up, which were usually zero. Three of them took only one value of 1, one took two values of 1 and these were omitted from the analysis. The different regression analyses yielded similar but not identical findings but did allow us to identify the most significant factors.

Multiple regression analysis was used for each of the dependent variables on the set of dependent variables. This procedure is sufficiently robust to withstand reasonable departures from normality, but the case of subjective hoarseness requires special comment. This can only take three different values, and as these are rather unequally

Table 3. Analysis of 54 patients complaining of hoarseness after tracheal intubation.

Duration	Number of patients		Mean duration of hoarseness (days)	Number of patients hoarse after 7 days (duration of hoarseness in parenthesis)
Mild	41	(25%)	5.5	2 (12,99)
Severe	13	(8%)	9.3	3 (9,10,54)
Overall	54	(32%)	6.4	5

weighted, the required assumption of homoscedacity (constancy of variance) would not be true. Nevertheless, the findings, as regards the ordinary multiple regression, would probably still be approximately true. This is supported by the fact that similar findings were found for the other variables used. However, in addition to the ordinary multiple regression, a logistic regression was carried out for the dependent variable, subjective hoarseness. In this case, using forward and backward stepwise, and ordinary full multiple regression (all logistic), just three factors were found to be significantly related to the hoarseness: females had more hoarseness than males, those intubated had more hoarseness, and the larger the tracheal tube, the greater the hoarseness.

For each of the dependent variables used, different types of multiple regression were carried out. There were stepwise, forward and backward regressions, full multiple regressions and maximum R squared regression. All these and the logistic regressions were carried out using the SAS statistical package [7]. Although many statistical tests were carried out, and in multiple-hypothesis testing there is a danger of obtaining some spurious significance, the validity of the present findings has been supported in two ways: (i) there were similar findings in the different regression analysis on each dependent variable—our summary of findings reports significances only when at least two of the analyses produced them; (ii) there were similar findings between the different (but related) dependent variables.

The factors which showed a significant correlation ($p < 0.05$) with the patient's assessment of hoarseness are given in Table 4. A '+' indicates a factor increasing the patient's subjective hoarseness and/or time to full recovery and '−' the reverse.

Discussion

The insertion of a tracheal tube can damage the upper respiratory tract resulting in a haematoma, laceration or granuloma of the mucosa, or arytenoid cartilage damage [2,6]. The tube may also damage the anterior branch of the recurrent laryngeal nerve with the larynx causing cord paralysis [8] or the external laryngeal nerve causing cricothyroid muscle paralysis [3]. These factors may result in hoarseness and some studies have tried to identify the causative factors [1,2,4,9]. It is often unclear what statistical methods have been used to analyse their data and no clear-cut factors have evolved.

The data from our prospective study have revealed factors which affect postintubation hoarseness. Most of these were not surprising. The use of thiopentone and methohexitone allowed a smooth, easy induction in preparation for intubation, whereas adverse conditions resulted in more pharyngeal trauma and hoarseness. The use of an introducer probably reflects difficulty in intubation. It was also reassuring that consultants appear to cause less hoarseness than more junior intubators. Interestingly, the weight of the patient had a positive correlation and probably reflects the greater technical difficulty in intubating obese patients. Most of the tracheal tubes used were Portex theatre tubes with standard cuffs. The Rae and

Table 4. Factors found to significantly ($p < 0.05$) affect the larynx in intubated patients. '+' indicates a factor increasing the patient's subjective hoarseness and/or time to full recovery and '−' the reverse.

	Patient subjective hoarseness at 24 hours	Time to full recovery
Weight	+	+
Pharyngeal drying agent		−
Thiopentone and methohexitone		−
Dose of thiopentone and methohexitone		−
Gallamine	+	
Dose of gallamine		+
Use of local anaesthetic spray to cords	+	
Difficult intubating conditions	+	
Use of introducer		+
Rae preformed tracheal tubes and Mallinckrodt long reinforced PVC tracheal tubes	+	
KY jelly tube lubricant	−	−
Lignocaine gel tube lubricant	+	−
Increasing duration of anaesthesia	+	
Consultant intubators	−	−

Mallinckrodt long reinforced PVC tracheal tubes were not in common use during the period of study and our findings, that they contributed to hoarseness, may reflect unfamiliarity with their use. We also found that an increasing duration of anaesthesia was related to an increased incidence of hoarseness. This is not surprising as tracheal intubation causes mucosal damage [10]. The longer the tube is in place, the greater the laryngeal damage, as previously reported [11]. Logically, the use of a bland lubricant such as KY gel should reduce trauma from tracheal intubation. Indeed, this is what we found, although other studies found no such difference [4].

Other findings were not so straightforward. We found that the use of local anaesthetic gel as a lubricant caused hoarseness, a finding observed by others [12]. However, some studies found either no difference [9] or the opposite to be true [13]. In our study, the use of lignocaine gel appeared to reduce the duration of hoarseness. A possible explanation is that local anaesthetics applied to the larynx may affect proprioception within it and lead to short, temporary hoarseness. This would also explain our observation that local anaesthetic spray to the larynx caused hoarseness.

The use of gallamine causing hoarseness appears inexplicable. The agent is not in common use now and our observation may reflect unfamiliarity with it, leading to inadequate paralysis at intubation. The other inexplicable finding is that pharyngeal drying agents reduced the time for hoarseness to recover and one may postulate that less suction is required in the dry pharynx, thus reducing overall physical trauma.

Although the incidence of hoarseness has been reported to be about 4–5% in some series [1,3], the incidence of 32% in our series is comparable to the 27–42% [4,5] reported in other series. Although two of our patients were hoarse for 54 and 99 days respectively, there were no patients with permanent voice changes. Larger series have also reported prolonged hoarseness after tracheal intubation. A study of 1000 patients [6] found nine (0.9%) to be hoarse 3 months later and in another study [2] one patient out of 475 (0.2%) was hoarse 2 months later. Neither of these studies state what the final outcome was.

A smaller study than ours comprised 100 women undergoing a mastectomy as a control group for comparison of voice changes in patients undergoing thyroidectomy. Of the 100 women undergoing mastectomy, 5% had some voice change after intubation, which persisted for more than 6 months in 3% [3]. We find this figure alarming and surprising, but it is unclear from this paper how the voice assessment was performed.

This prospective study supports a low incidence of prolonged hoarseness following short-term/tracheal intubation and indicates that a thin patient, intubated by a consultant anaesthetist using KY jelly is at very little risk of permanent voice damage.

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Anaesthesia, 1992, Volume 47, pages 217–219

Suxamethonium block in the myasthenic patient

Correlation with plasma cholinesterase

A. BARAKA

Summary

The neuromuscular block of suxamethonium 1.5 mg.kg^{-1} was investigated in three myasthenic patients (Class IIA), undergoing thymectomy. Two of the patients were receiving pre-operative pyridostigmine therapy. In the three patients, plasma cholinesterase activity was determined on the morning of surgery and was correlated with the neuromuscular response to suxamethonium as monitored by electromyography. The results suggest that the response to suxamethonium in the myasthenic patients can show wide variations according to the level of their plasma cholinesterase activity. The degree and duration of suxamethonium block is inversely related to the plasma cholinesterase activity.

Key words

Neuromuscular relaxants; suxamethonium.
Complications; myasthenia gravis.

Resistance to suxamethonium has been shown in the myasthenic patient [1], and in those with ocular myasthenia the resistance seems to be in the uninvolved muscles [2]. However, myasthenic patients during a true remission may not demonstrate resistance [3]. Treatment of myasthenic patients by anticholinesterases can decrease plasma cholinesterase activity and delay the hydrolysis of suxamethonium [4, 5]. Thus, myasthenic patients treated with anticholinesterases may exhibit a prolonged suxamethonium neuromuscular block, although this is poorly documented [6].

The present report investigates the neuromuscular block of suxamethonium in three myasthenic patients, and correlates the response with plasma cholinesterase activity.

Method

Investigation was carried out in three myasthenic patients undergoing thymectomy via midsternotomy. The three patients were suffering from generalised myasthenia gravis (Osserman grade 11A) [7]. Patients' data are presented in Table 1.

Patients were medically treated prior to thymectomy for 2–6 months. In the first patient, no anticholinesterase therapy was used, while oral pyridostigmine 60 mg 6 hourly, was used in the second and third patients. Pyridostigmine was discontinued the evening of surgery in the second patient, and was continued until the morning of surgery in the third patient. On the morning of surgery, plasma cholinesterase activity was measured in the three patients, using spectrophotometry and pro-prionylthiocholine as a substrate [8]. Also, dibucaine numbers were determined.

Neuromuscular transmission was monitored in the operating theatre by electromyography by a Datex Relaxograph (R) monitor. The ulnar nerve was stimulated supramaximally at the wrist every 20 s, and the resulting electromyographic response displayed. The monitor uses the train-of-four principle at a stimulus frequency of 2 Hz, and computes the ratio of the fourth to the first evoked response (T4/T1 ratio), as well as the T1/control ratio.

The three patients were premedicated with intramuscular atropine 0.6 mg and oral diazepam 5 mg. Anaesthesia was induced with thiopentone 5 mg.kg^{-1}. Following induction of anaesthesia and while the patients were breathing 100% oxygen, the electromyographic response was recorded. When a steady response was achieved, suxamethonium 1.5 mg.kg^{-1} was injected intravenously and the neuromuscular response was monitored. When maximal neuromuscular block was achieved, the trachea was intubated, and anaesthesia was maintained with 65% nitrous oxide in oxygen supplemented by 5 μg.kg^{-1} fentanyl. The degree of block achieved by suxamethonium and the time required for 75% recovery of T1/control ratio was recorded.

Following recovery from suxamethonium blockade, incremental doses of 0.01 mg.kg^{-1} vecuronium were used to maintain muscle relaxation throughout surgery. At the termination of surgery, residual neuromuscular blockade

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Table 1. Patient data.

Patient	Age (years)	Sex	Classification	Treatment
1	14	F	IIA	Plasmapheresis (3 sessions) Prednisone 25 mg.day^{-1} Azathioprine 150 mg.day^{-1}
2	30	F	IIA	Pyridostigmine 60 mg 6 hourly
3	67	M	IIA	Pyridostigmine 60 mmg 6 hourly

Table 2. The plasma cholinesterase activity and the dibucaine number in the three patients. Normal value in our population is 2.5-6 units.ml^{-1}.

Patient	Plasma cholinesterase activity (U.ml^{-1})	Dibucaine number
1	5.16	90
2	1.45	90
3	0.73	88

was reversed by a mixture of neostigmine 0.05 mg.kg^{-1} and atropine 0.02 mg.kg^{-1}.

Results

Plasma cholinesterase

As shown in Table 2, the plasma cholinesterase was normal in the first patient who was not receiving pyridostigmine. In the second patient whose anticholinesterase therapy was discontinued the evening of the surgery, the plasma cholinesterase was moderately decreased, while it was markedly decreased in the third patient whose therapy was continued till the morning of surgery. In the three patients, the dibucaine number was within the normal range denoting homozygous typical enzyme $[E_{1u}E_{1u}]$.

Table 3. This shows the plasma cholinesterase activity and the corresponding time to 75% recovery of the T1/control ratio.

Patient	Plasma cholinesterase activity (U.ml^{-1})	Recovery time (min)
1	5.16	3
2	1.45	16
3	0.73	35

Suxamethonium neuromuscular block

As shown in Figure 1, suxamethonium 1.5 mg.kg^{-1} did not result in complete neuromuscular block in the first patient. Also, 75% recovery of the T1/control ratio was rapidly achieved after 3 min. In the other two patients, suxamethonium produced complete neuromuscular blockade. Seventy-five percent recovery of T1/control ratio was achieved after 16 min in the second patient and after 35 min in the third patient.

The recovery times in the three patients were inversely related to their plasma cholinesterase activity (Table 3).

Discussion

Myasthenia gravis is an autoimmune disease that results from the production of autoantibodies against the acetylcholine receptors of the neuromuscular synapse, with subsequent reduction in the functional endplate receptors. Reduction in the number of receptors is brought about either by an increased rate of degradation, or by functional blockade [9].

The decreased number of endplate receptors can decrease the response to the chemical transmitter acetylcholine, as well as to the depolarising action of decamethonium [10] and suxamethonium [1, 2]. This can explain the resistance to suxamethonium block which was observed in the first myasthenic patient who was not treated by anticholinester-

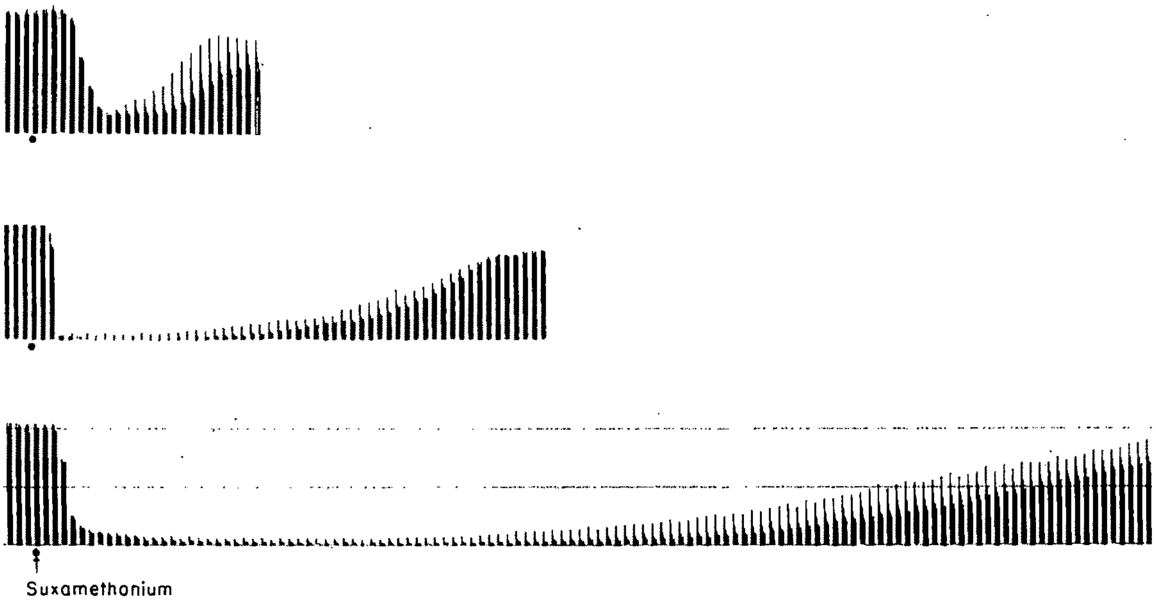

Fig. 1. Electromyographic response to ulnar nerve stimulation by a train-of-four every 20 s, showing the effect of suxamethonium 1.5 mg.kg^{-1}. In the first patient (upper tracing), only partial block was achieved and 75% recovery of T1/control ratio was observed after 3 min. In the second patient (middle tracing), complete block was achieved and 75% recovery was observed after 16 min. In the third patient (lower tracing), 75% recovery was achieved after 35 min.

ases. In the other two patients treated with pyridostigmine, suxamethonium produced complete and prolonged neuromuscular block.

The different response to suxamethonium in the three myasthenic patients may be attributed to the different plasma cholinesterase activity. The plasma cholinesterase activity was normal in the first patient, while it was moderately decreased in the second patient and markedly reduced in the third patient. Anticholinesterases have been shown to decrease the plasma cholinesterase activity [4], and hence can result in decreased hydrolysis of suxamethonium with a subsequent potentiation of its neuromuscular block [5]. Similar to nonmyasthenic patients, our myasthenic patients showed an inverse relationship between the duration of suxamethonium block and the plasma cholinesterase activity [11].

In conclusion, the present report shows that the neuromuscular block of suxamethonium in the myasthenic patient can show wide variations. Myasthenic patients may show resistance to suxamethonium. However, the use of anticholinesterase therapy with the subsequent decrease in plasma cholinesterase activity can decrease the rate of hydrolysis of suxamethonium and potentiate its neuromuscular block. The degree of potentiation of blockade is inversely related to the plasma cholinesterase activity.

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Anaesthesia, 1992, Volume 47, pages 220–222

CASE REPORT

The use of high-dose intravenous immunoglobulins in Guillain–Barré syndrome

A. RAJAH

Summary

A patient with severe Guillain–Barré syndrome responded to treatment with high-dose intravenous immunoglobulins. It is suggested, on the basis of recent case reports, that immunoglobulins may have an important rôle in the future treatment of this immune-mediated disease.

Key words

Complications; Guillain–Barré syndrome.
Immunoglobulins.

Guillain–Barré syndrome is a demyelinating disease of peripheral nerves which causes a flaccid paralysis, autonomic dysfunction and minor sensory symptoms. Despite modern intensive medical care and respiratory support, the mortality rate is approximately 5% [1]. In addition, 10–30% of the patients require tracheostomy at some stage of their illness, 3–10% experience relapses, and up to 20% have residual disability [2–4]. The likelihood of permanent disability increases with the severity and duration of the disease, and patients may require prolonged hospital care [5]. There is, therefore, urgent need for a form of treatment that would decrease the severity of the acute phase of the disease and shorten the recovery period.

There is increasing evidence to suggest that this syndrome has an immunological basis and this has led to the use of plasmapheresis and immunoglobulins in severe Guillain–Barré syndrome. However, plasmapheresis itself is associated with morbidity and mortality and it can only be undertaken in hospitals which have appropriate facilities and personnel experienced in performing the procedure on critically ill patients [6].

Case history

A 9-year-old boy who was previously healthy was admitted with a 5-day history of generalised arthralgia and myalgia, mainly in the lower limbs, and an inability to straighten his legs because of pain. He continued to deteriorate over the next 2 days. The weakness in the lower limbs became more marked and progressed to involve all muscle groups such that he was unable to rise from a recumbent position or even to roll in bed. This was associated with diminished sensation to pain and touch in the lower limbs and decreased muscle stretch reflexes. In addition, there was evidence of cranial nerve involvement, with marked facial weakness, decreased pharyngeal reflexes and diplopia.

His forced vital capacity was 0.7 l which was 32% of the predicted value. Arterial blood gases on breathing room air were as follows: pH 7.47 $P\text{a}\text{CO}_2$ 4.8 kPa, $P\text{a}\text{O}_2$ 13.6 kPa and oxygen saturation 98%. Lumbar puncture was performed and the cerebrospinal fluid protein level was in excess of 1 g.l^{-1} with no increase in the cell count. Cytomegalovirus was isolated from the urine. A diagnosis of Guillain–Barré syndrome was made and he was admitted to the intensive care unit where high-dose immunoglobulin therapy was started. Sandoglobulin (Sandoz Pharmaceuticals) was given intravenously at a dose of 1 g.kg^{-1}.day^{-1} over 2 consecutive days. The heart rate, blood pressure, respiratory rate and temperature were monitored during treatment and any side effects were noted. The patient was assessed daily with particular reference to muscle strength and vital capacity.

During treatment, the progression of the disease stopped and thereafter slow recovery took place. The signs of cranial nerve involvement improved in parallel with the improvements in strength of trunk and limb muscles, such that at the end of 5 days' therapy, complete resolution had occurred. Soon afterwards considerable improvements in

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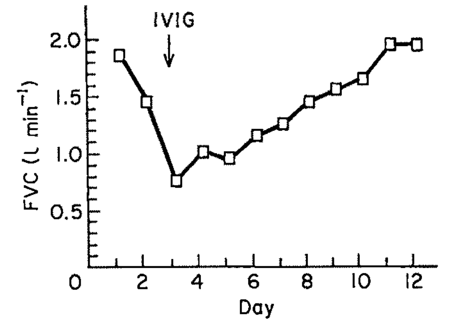

Fig. 1. Changes in forced vital capacity from day 1 to day 12. □, FVC, forced vital capacity (l.min^{-1}); IVIG, intravenous immunoglobulins.

spirometric value were noted (Fig. 1). No further therapy was needed, although full supportive measures were given and intensive physiotherapy undertaken.

Four weeks after admission, the patient was able to walk with the aid of crutches. Good muscle tone and power had returned to the upper limbs, although the lower limbs were still markedly wasted. On his first outpatient follow-up visit, 3 months later, he had completely recovered from his illness and no abnormality of his musculoskeletal system or cranial nerve function was detected.

Discussion

The first report of acute ascending paralysis was by Landry in 1959 [7]. Guillain *et al.* [8] described the syndrome in greater detail including the characteristic changes in cerebrospinal fluid. Subsequent work [9–13] has shed further light on a condition which, in its severe form, may tax the resources of an intensive care unit to its fullest extent.

Early accounts of the syndrome describe the progressive onset of an ascending symmetrical paraesthesia and paralysis, which initially affects the lower limbs and may progress to the upper limbs and trunk, with involvement of the respiratory muscles and cranial nerves occurring in severe forms of the disease [7, 8, 10]. The history of viral exposure, the rate of progression of symptoms, the degree of nerve involvement, the duration of symptoms, and the occurrence of pain are all variable features and no universal pattern can be said to occur [11]. Despite this variability of symptoms and signs, the diagnosis is usually made clinically, but is confirmed by examination of the cerebrospinal fluid. This usually shows an increase in protein content, which may be substantial, but is not accompanied by a corresponding rise in the cell count. Measurement of nerve conduction velocity shows slowing of conduction and this may be of prognostic value.

There is increasing evidence that the segmental demyelination of peripheral nerves, which forms the pathological basis of this disorder, is immunologically mediated. The association of antiperipheral nerve myelin antibodies with damage to myelin [14, 15] and the ability to induce demyelination in animals injected with serum obtained from patients with Guillain–Barré syndrome [16], lends strong support to this theory. The rationale for the use of plasmapheresis and high-dose immunoglobulins is based on this evidence.

Various methods of treatment have been advocated to modify the course of the disease. At present, the majority of cases of Guillain–Barré syndrome are managed with supportive and symptomatic measures alone until spontaneous recovery begins. Steroids have been given on the basis that the disorder is allergic; however, the evidence in their favour is anecdotal, and a controlled trial showed that the use of prednisolone was of no benefit and might even be detrimental [17]. Several reports of small and uncontrolled trials [18–24] and recent randomised prospective trials [25–28] showed benefit from the use of plasmapheresis early in the disease in severely affected patients. Plasmapheresis reduced both the duration of the disease and the risk of respiratory failure [6]. However, the procedure, undertaken in acutely ill patients who have respiratory depression and autonomic instability, is not without complications. It requires the insertion of a central venous catheter and is associated with fluid imbalance, haemorrhage, haemolysis, hypocalcaemia and the transmission of infection [6]. In addition, it is unsuitable for children who are less than 2 years old.

In contrast, immunoglobulins are widely available, can be easily administered without delay [29, 30] and are safe and cheap. Sandoglobulin is a concentrated, polyvalent immunoglobulin preparation which contains all the antibodies normally present in the donor pool. It is prepared by cold alcohol fractionation of pooled plasma and contains at least 96% IgG. It is available as a freeze-dried preparation which can be reconstituted with 0.9% sodium chloride to form either a 3% or 6% solution. Once reconstituted, it should be used without delay. There are a few recent reports in the world literature in which high-dose intravenous immunoglobulins have been successfully used in the treatment of Guillain–Barré syndrome [31, 32] even in severely affected patients unresponsive to plasmapheresis [33]. The use of high-dose immunoglobulins in four children and eight adults has been documented. In seven of the nine patients who were treated with immunoglobulins alone, significant improvement occurred within 24 h of the onset of treatment and none of the seven patients had the plateau phase which is characteristic of those severely affected by Guillain–Barré syndrome. Immunoglobulins were also successfully used in two patients following deterioration after plasmapheresis. One other patient was totally unresponsive to plasmapheresis but improved dramatically after receiving intravenous immunoglobulins.

In view of these experiences and the fact that the condition is uncommon, there is a need for multicentre controlled studies to evaluate this new method of treatment.

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Anaesthesia, 1992, Volume 47, pages 223–225

CASE REPORT

Treatment of acute severe asthma assisted by hypothermia

D. BROWNING AND D. T. GOODRUM

Summary

A 20-year-old woman in status asthmaticus who failed to respond to conventional therapy and ventilation of the lungs with 0.5–2.0% halothane, was cooled to 30°C for almost 5 days as the arterial carbon dioxide tension rose above 15 kPa. Halothane was not of immediate value, contrary to other reports. A reduction in carbon dioxide production by controlled hypothermia permitted more suitable ventilation parameters, but extensive muscle weakness caused by a steroid-induced myopathy complicated weaning from respiratory support. Prospective measurement of serum creatinine phosphokinase concentration in patients given high dose corticosteroids may herald the onset of a myopathy.

Key words

Lung; asthma.
Hypothermia.

Asthma is a common disease, prevalent in 1–3% of the adult population. On rare occasions, when conventional therapy is unsuccessful, mechanical ventilation may be necessary to maintain adequate gas exchange. We report a case in which additional measures were required.

Case history

A 20-year-old asthmatic woman was admitted to a medical ward with increasing dyspnoea and wheeze. She was distressed, tachypnoeic, and had a tachycardia of 120 beat.min^{-1}. Chest auscultation revealed poor air entry with a quiet expiratory wheeze. There was no radiological evidence of a pneumothorax or mediastinal emphysema. Peak expiratory flow was 60 l.min^{-1}. Arterial blood gas analysis breathing 40% oxygen showed pH 7.24, $P\text{aO}_2$ 13.82 kPa and $P\text{aCO}_2$ 6.91 kPa.

Despite conventional treatment she became exhausted and was transferred to the intensive care unit with a respiratory rate of 42 breath.min^{-1}, heart rate 140 beat.min^{-1} and pH 7.2, $P\text{aO}_2$ 23 kPa and $P\text{aCO}_2$ 7.9 kPa on $F\text{IO}_2$ 0.6.

The trachea was intubated, and the lungs ventilated using an Engstrom Erica ventilator, initially with a rate of 12 breath.min^{-1}, tidal volume 600 ml, I:E ratio 1:1 and $F\text{IO}_2$ 0.5. This resulted in airway pressures of 60 cmH$_2$O. She was sedated using a propofol infusion and muscle relaxation was achieved with vecuronium at a rate of 6 mg.h^{-1}.

Intravenous salbutamol was given at a rate of 40 μg.min^{-1}, aminophylline at a rate of 0.5 mg.min^{-1} and hydrocortisone 800 mg daily. These were supplemented by warm saline bronchopulmonary lavage, and airway pressures of 40 cmH$_2$O were achieved. An adrenaline infusion was administered at a rate of 200 μg.h^{-1}, but without benefit.

After 6 h of ventilation the inflation pressure rapidly returned to over 60 cmH$_2$O. Reduction of the respiratory rate to 8 breath.min^{-1} and tidal volume to 550 ml had little effect. Airway pressure increased to 70 cmH$_2$O, $P\text{aO}_2$ was satisfactory (14.5 kPa) but $P\text{aCO}_2$ increased to 8.7 kPa. Progressive deterioration occurred over the next 12 h. Significant surgical emphysema developed without radiological evidence of a pneumothorax and blood gas analysis showed pH 7.01, $P\text{aO}_2$ 12.0 kPa and $P\text{aCO}_2$ 15.7 kPa.

Attempts to alleviate the situation included drainage of both pleural cavities, bronchopulmonary lavage, intravenous ketamine and ventilation with 0.5–2% halothane. These modes of therapy had minimal effect on the airway pressures.

A Sheffield Hypothermia Unit was used to reduce the patient's core temperature to 30°C, and to decrease CO$_2$ production. By the third day, some reduction in $P\text{aCO}_2$ had been achieved. Blood gas analysis (temperature-corrected

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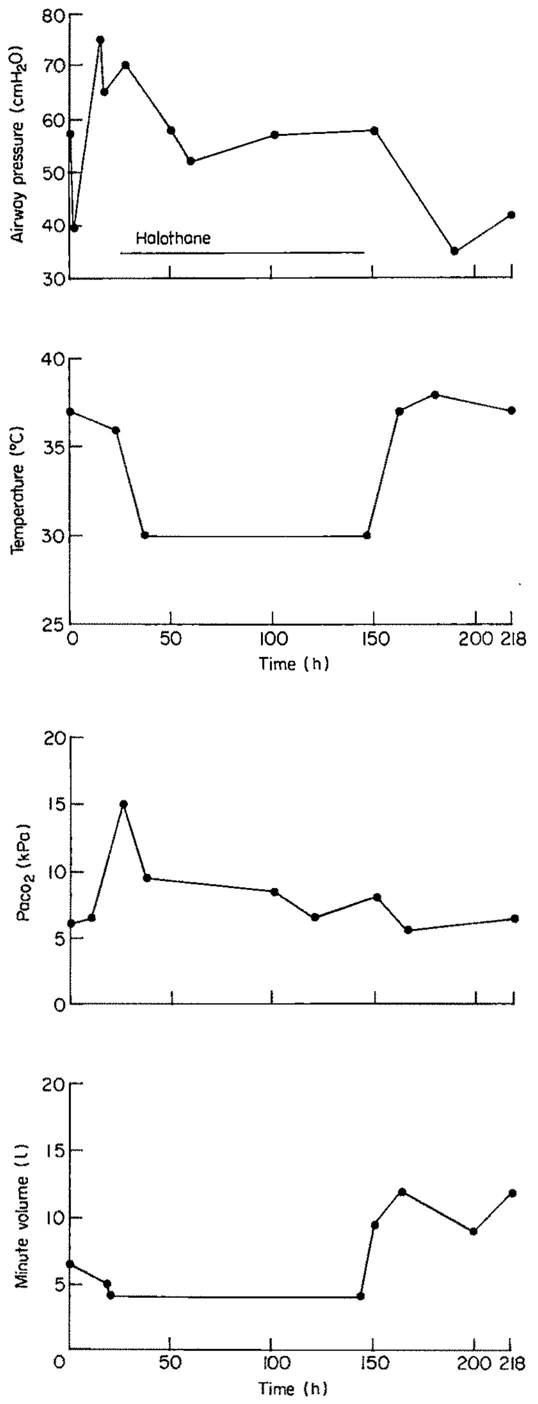

Fig. 1. Changes in airway pressure, temperature, $Paco_2$, and minute volume after institution of mechanical ventilation (time 0).

to 37°C) revealed pH 7.17, Pao_2 12.5 kPa and $Paco_2$ 9.47 kPa. Halothane therapy and controlled hypothermia continued for 5 days. There were no significant arrhythmias or hypotensive episodes with 0.5%–1% halothane, and serum theophylline concentration was kept at 15 μg.ml^{-1}.

Figure 1 depicts the gradual improvements in airway pressure, $Paco_2$ and minute volume which occurred particularly on the 7th day. Halothane therapy was withdrawn slowly and gradual warming commenced. It was apparent that weaning would be difficult when weak respiratory effort returned 2 days later, despite normal electrolytes and nutritional support.

On examination she appeared alert with normal sensation, but with severe limb and respiratory muscle impairment and reduced peripheral reflexes. A diagnosis of polymyopathy was supported by an elevated serum creatinine phosphokinase concentration of 2709 IU.l^{-1}. Muscle biopsy revealed focal damage to muscle fibres and plasma membranes, features consistent with a drug-induced abnormality. Serum aspartate aminotransferase concentration was elevated for 19 days, to a maximum of 150 IU.l^{-1} 9 days after introduction of halothane.

A temporary tracheostomy after 15 days assisted weaning from respiratory support. The patient was transferred from the intensive care unit 28 days after admission, and returned home fully recovered 4 weeks later.

Discussion

Mortality figures from several large studies of patients with severe asthma range from 0–2.3%, with an incidence of mechanical ventilation of between 0.1 and 16% [1–5]. These deaths were due to cardiovascular collapse following positive pressure ventilation of patients' lungs with bilateral tension pneumothorax, or with septic shock complicated by multi-organ system failure.

Numerous reports confirm the benefit of halothane in life-threatening asthma [6–11] and few cases have been recorded in which halothane has been of little help [12, 13]. The use of volatile anaesthetic agents in the treatment of asthma is not without risk [14]. Ketamine infusion [15] and selective bronchopulmonary lavage [16] have been used in severe refractory cases when ventilation with volatile agents is unsuccessful even with maximal bronchodilator and corticosteroid therapy.

The rarity of death from hypercapnia, compared with numerous reports of death from bilateral pneumothorax, fuel the debate between accepting high $Paco_2$ levels or dangerously high airway pressures [2,4,5,17]. Limitation of peak pressure to 50 cmH$_2$O has been recommended by Darioli and Perrat [3] but they also quote the safe upper limit for $Paco_2$ as 12 kPa.

When considering the question of how high $Paco_2$ and airway pressures should be allowed to rise, it is useful to review two reports of severe asthma treated successfully using extracorporeal respiratory support.

In one case [12], peak airway pressure was 85 cmH$_2$O and $Paco_2$ reached 14 kPa; the patient developed signs of raised intracranial pressure. In the second case [18], airway pressure reached 80 cmH$_2$O and $Paco_2$ increased to 15.7 kPa, hypotension being evident. The patient described in this report, whilst haemodynamically stable, demonstrated airway pressures of 70 cmH$_2$O associated with a steadily increasing $Paco_2$ to over 15.7 kPa when cooling was instituted.

The use of hypothermia to reduce carbon dioxide production has been described in pigs [19], but not to our knowledge for the treatment of asthma in man. Cooling the patient reduced the metabolic rate, enabling the minute volume to be decreased to 3 l.min^{-1}, and achieved a temperature-corrected $Paco_2$ of 9.47 kPa.

The complex relationship between $Paco_2$ and temperature has been addressed by several authors [20–23]. Arterial blood samples from patients at 30°C are heated to 37°C in blood gas machines before analysis. During this process, $Paco_2$ increases because of variations in weak acid dissociation, notably carbonic acid and protein imidazole groups [23]. The correct $P\mathrm{aco}_2$ of the patient is found by a mathematical formulation using the measured value at 37°C [22,24]. The effects of hydrogen ions and $P\mathrm{aco}_2$ on enzyme systems and homeostasis are temperature dependent [21]. Irrespective of the patient's temperature the enzyme systems respond to pH and $P\mathrm{aco}_2$ in a manner similar to the pH and $P\mathrm{aco}_2$ as measured at 37°C. Thus, cooling the patient prevented the $P\mathrm{aco}_2$ from rising further, while physiologically, the response to a $P\mathrm{aco}_2$ of 10.7 kPa at 30°C would be identical to a $P\mathrm{aco}_2$ of 15 kPa at 37°C. However, reducing carbon dioxide production did allow a lower minute volume of ventilation and lower airway pressures.

Although the treatment described here was successful it was not without complication. Extreme muscle weakness prevented weaning from the ventilator until the 17th day. Seven other reports have described the complication of delayed weaning from respiratory support in asthmatics because of muscle weakness. Five of these attributed blame to a steroid-induced myopathy [25–28]. One of the remaining two reports was ascribed to disuse atrophy after 14 days of ventilation [29] and in the other, which followed 3 days of halothane therapy, no explanation was offered [6]. One might speculate that the cause of the delayed weaning in these two cases was of steroid origin. Williams [28] has summarised the five previous cases of steroid-induced myopathy and there are similarities between these and the case presented. Four of the patients were young females who received hydrocortisone 1–3 g.24 h^{-1}. Muscle weakness was manifested by failure to wean from respiratory support, while they all had significant limb weakness, facial muscle sparing and unimpaired sensation. The average time from admission to diagnosis was 8.4 days and the serum creatinine phosphokinase concentration was elevated in three of five patients.

In conclusion, this case has demonstrated that hypothermia can be used to reduce carbon dioxide production in severe asthma, and should alert clinicians to the possibility of steroid-induced myopathy causing delayed weaning from respiratory support. We suggest that regular measurement of serum creatinine phosphokinase may indicate the onset of a developing myopathy.

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Anaesthesia, 1992, Volume 47, pages 226–228

CASE REPORT

Reversal of streptokinase-induced bleeding with aprotinin for emergency cardiac surgery

T. M. AKHTAR, C. S. GOODCHILD AND M. K. G. BOYLAN

Summary

Two patients requiring emergency cardiac surgery following the administration of streptokinase are described. In each case aprotinin was given to counteract the haemorrhagic effects of the streptokinase.

Key words

Aprotinin.
Surgery, cardiovascular; emergency, haemorrhage.
Streptokinase.

The use of streptokinase in the management of acute myocardial infarction is increasing, but emergency cardiac surgery performed within 12 h of the administration of streptokinase results in massive haemorrhage [1]. Aprotinin preserves platelet function during extracorporeal circulation and, by other mechanisms not yet known, reduces postoperative blood loss. It may also specifically antagonise the haemorrhagic effect of streptokinase [2]. There are no reports of its use in emergency cardiac surgery following streptokinase administration, although its role in aortic surgery has been described [3]. We report two cases who required emergency cardiac surgery following streptokinase administration where the use of aprotinin reduced postoperative blood loss.

Case histories

Case 1

A 73-year-old, diet-controlled diabetic man presented with unstable angina. He had suffered from angina pectoris and shortness of breath for the last 12 years; triple-vessel disease had been diagnosed by coronary arteriography and his symptoms were well controlled with metoprolol and nifedipine. He had had one episode of myocardial infarction 4 years before this admission and had undergone bypass grafting of the right and left anterior descending coronary arteries at that time. At surgery the vessels were found to be very small and revascularisation of the myocardium was incomplete and resulted in no relief of his angina.

In the 14 days preceding the present admission to hospital his angina was uncontrollable with medication. On the seventh day after admission to hospital he had severe retrosternal pain which was resistant to glyceryl trinitrate treatment; the electrocardiogram (ECG) showed acute inferior myocardial ischaemia. Dyspnoea increased and pulmonary oedema was diagnosed by chest X ray.

One and a half million units of streptokinase were administered about 6 h after the ischaemic episode; ST segment elevation persisted. It was therefore decided to perform emergency percutaneous transluminal coronary angioplasty (PTCA). Coronary catheterisation revealed a patent right coronary artery graft, 80% stenosis of the left circumflex coronary artery and complete blockage of the left anterior descending artery graft by an adhering plaque and a large thrombus. PTCA did not improve the patency of the anterior descending coronary artery graft and there was a persistent ST segment elevation on the ECG. An intraluminal stent was left *in situ* to maintain patency of the vessel and the decision was taken to perform an emergency re-operation for coronary artery bypass grafting.

The patient presented for anaesthesia and surgery 5 h after streptokinase administration. Cardiovascular monitoring lines were inserted and general anaesthesia was induced with midazolam and diamorphine. The trachea was intubated and the lungs ventilated with 100% oxygen. Cardiovascular support by inotrope and vasodilator therapy was required before cardiopulmonary bypass. Two

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million kallikrein inactivator units (KIU) of aprotinin (Trasylol, Bayer) were administered 12 min before the institution of cardiopulmonary bypass to reverse the effect of the streptokinase. Another one million KIU were given into the cardiopulmonary bypass circuit. An aprotinin infusion of 500 000 KIU per h was continued throughout the operation and for 4 h postoperatively.

Anticoagulation was achieved with heparin 300 IU.kg^{-1}; no further heparin was needed during bypass. Five minutes after the administration of heparin, the activated clotting time (ACT) was 1050 s (control before heparin administration 165 s). Coronary artery vein grafts to the left anterior descending and left circumflex artery were performed using induced ventricular fibrillation to produce cardiac standstill rather than cardioplegia solution. Two hours after the administration of heparin, ACT was greater than 230 s. Multiple inotropic support as well as an intra-aortic balloon pump were necessary to wean the patient from cardiopulmonary bypass. Protamine 200 mg was then given to reverse the effect of heparin. Clotting studies were performed 5 min later (Table 1); prothrombin time 56 s (control 15 s), activated thromboplastin time 107 s (control 32 s); platelets 152×10^9 l^{-1}, fibrin degradation products 0.25–0.5 μg.ml^{-1} (normal < 20 μg.ml^{-1}) and no detectable fibrinogen.

Clotting studies were repeated after administering four units each of fresh frozen plasma, cryoprecipitate and platelets: platelet count 191×10^9 l^{-1}; prothrombin time 33 s (control 15 s); activated thromboplastin time 122 s (control 32 s); fibrin degradation products 0.25–0.5 μg.ml^{-1}. Blood loss was not excessive, being 375 ml in the first hour and 125 ml in the second. Total postoperative blood loss was 1285 ml (Fig. 1).

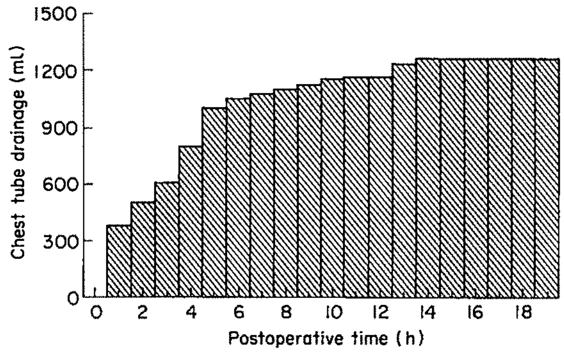

Fig. 1. Cumulative postoperative blood loss in the first patient.

Case 2

A 67-year-old female was admitted with severe chest pain, shortness of breath, syncope and palpitation. On admission she was drowsy, pale and clammy. Her arterial pressure was 160/94 mmHg and pulse 64 per minute and regular. The ECG confirmed inferior myocardial infarction. Intravenous streptokinase 1.5 million units, oral nitrate and subcutaneous heparin were given.

Ninety minutes after the streptokinase therapy, chest pain recurred with a marked elevation of ST segments in the inferior and lateral ECG leads. Systolic arterial pressure decreased to 60 mmHg resulting in poor peripheral perfusion. Intra-aortic balloon pumping was instituted but ST segment elevation persisted. Emergency coronary angiography showed 90% stenosis of the left anterior descending artery which was successfully dilated by percutaneous transluminal intracoronary angioplasty, but it did not improve the haemodynamic parameters. Echocardiography showed a pericardial effusion with right ventricular collapse. Attempts at pericardial aspiration resulted in right ventricular puncture and the patient was transferred to the operating theatre for emergency cardiac surgery. Arterial pressure was 80/50 mmHg in spite of inotropic support. Anaesthesia was induced with fentanyl 500 μg and pancuronium 12 mg was administered to facilitate tracheal intubation. Activated clotting time before operation was 186 s, was 600 s on administration of heparin 300 IU.kg^{-1} and 136 s after the reversal of heparin with protamine 1.5 mg per 100 IU of heparin administered. Aprotinin was administered using the same regimen as described for the first patient. Pericardial tamponade secondary to a transmural infarct was discovered and the defect was repaired under induced ventricular fibrillation. Bypass time was 60 min. Total postoperative blood loss was 215 ml (Fig. 2).

Discussion

It is only in the last 10 years that thrombolytic therapy has become commonplace in the treatment of myocardial infarction, where it has been shown to improve survival in selected patients [4]. Streptokinase should be administered within 6 h of the onset of acute myocardial infarction [5], and it is effective in achieving thrombolysis in about 50% of the patients [6]. Streptokinase acts indirectly on plasminogen and converts it into plasmin, but unlike second generation thrombolytic agents (e.g. tissue-type plasminogen activator) it is not fibrin selective and can produce a coagulopathy complicated by haemorrhage. Eight percent of patients treated with streptokinase may develop gastrointestinal haemorrhage, while 0.5% may have retroperitoneal bleeding [7]. Cases of pericardial tamponade have also been reported. Coagulopathy induced by streptokinase may take up to 3 days to resolve despite the

Table 1. Clotting studies.

	Before operation	Immediately after bypass	90 min after operation*	6 h after operation
Activated clotting time; s	165	1050		
Platelets; 10^9.l^{-1}		152	191	148
Prothrombin time; s		56/15	33/15	26/15
Activated partial thromboplastin time; s		107/32	122/32	126/32
Fibrinogen		None detected	None detected	None detected
Fibrin degradation products; μg.ml^{-1}		0.25–0.5	0.25–0.5	

*Four units were given each of platelets, cryoprecipitate, and fresh frozen plasma.

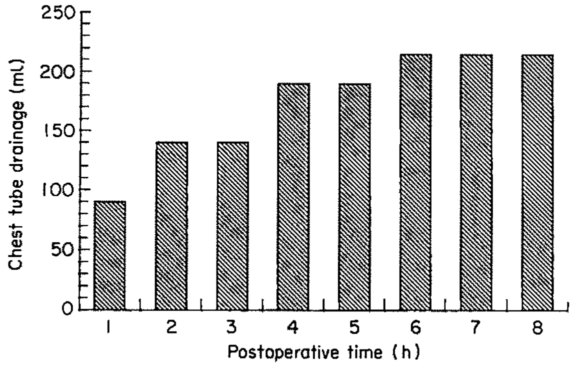

Fig. 2. Cumulative postoperative blood loss in the second patient.

administration of Vitamin K, fresh frozen plasma and platelets [3]. A major disadvantage of thrombolytic therapy administered alone is the high risk of re-occlusion and re-infarction [8] but its ease and rapidity of administration makes thrombolytic therapy the first choice in the management of most patients.

The second step in the management of patients not responding favourably to thrombolytic therapy is percutaneous transluminal coronary angioplasty (PTCA). It has been reported that more patients require emergency coronary artery bypass surgery if PTCA is performed immediately following streptokinase therapy [9]. As physicians increasingly use aggressive thrombolytic therapy in the management of acute myocardial infarction it seems inevitable that more of these patients will present for emergency cardiac surgery.

A number of therapeutic agents with a potential for reducing postoperative blood loss following open heart surgery have been investigated. Salzman *et al.* [10] investigated desmopressin and found higher levels of von Willebrand factor and a decrease in postoperative blood loss following complex cardiac surgery when it was administered at the end of cardiopulmonary bypass. Fish *et al.* [11] demonstrated a decrease in postoperative blood loss in the first 6 h following isolated coronary artery bypass graft surgery, when prostacycline (epoprostenol) was administered, but the total blood loss over 24 h was not significantly different from the placebo group. Protamine is a myocardial depressant and is used immediately after cardiopulmonary bypass. Prostacyclin reduces the requirement for heparin, therefore less protamine is needed to reverse it. However, its vasodilator properties decrease arterial pressure [12] and may compromise cerebral perfusion. Routine clinical use of prostacyclin is not recommended. There are no reports suggesting the use of desmopressin or prostacyclin to specifically reverse the haemorrhagic effect of streptokinase following cardiac surgery.

Aprotinin is a protease inhibitor which contributes to the re-establishment of haemostasis by inactivating free plasmin. It also inhibits the fibrinolytic activity of the plasmin-streptokinase complex. Use of aprotinin in routine cardiac surgery decreases postoperative blood loss to an average of about 286 ml compared with 1500 ml when aprotinin is not used [13]. Blood loss in our first patient was only 1285 ml. This blood loss is not excessive bearing in mind that the patient received streptokinase therapy, underwent an emergency cardiac re-operation and required a prolonged period of extracorporeal circulation. Bleeding stopped after 14 h and the chest drains were removed 20 h following surgery (Fig. 1). Kereiakes *et al.* have reported blood loss in excess of 400 ml in patients undergoing cardiac surgery following thrombolytic therapy [14]. We believe that the blood loss in these patients would have been considerably greater had we not used aprotinin.

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Anaesthesia, 1992, Volume 47, pages 229–230

CASE REPORT

Difficulty in extubation

A cause for concern

J. G. BROCK-UTNE, R. A. JAFFE, B. ROBINS AND E. RATNER

Summary

Difficulties in removing the tracheal tube from the trachea are relatively uncommon. We report here a case of difficult extubation which was precipitated by pulling off the pilot balloon and valve assembly in order to deflate the cuff.

Key words

Intubation, tracheal; complications, extubation.

The problem of difficult tracheal intubation is well known to anaesthetists; however, difficulties with extubation are not as common. We describe a difficult tracheal extubation which was caused by a relatively common practice among anaesthetists.

Case history

A 33-year-old female was scheduled for repair and replacement of a ventriculo-peritoneal (V-P) shunt. Her medical history included cerebral palsy which made her wheelchair-bound. She had had multiple surgical procedures under general anaesthesia without complication. Her weight was 42 kg, and her vital signs were normal.

General anaesthesia was induced with thiopentone 300 mg and maintained with isoflurane and nitrous oxide in oxygen, pethidine 30 mg and vecuronium 5 mg. She was intubated easily with a 7.0 mm Mallinckrodt Intermediate Hi-Lo cuffed tracheal tube. During the course of the procedure, the patient also received claforan 1 g and vancomycin 1 g at the surgeon's request, and metoclopramide 10 mg with hyoscine 0.2 mg as prophylaxis for postoperative nausea.

At the end of surgery, neuromuscular blockade was reversed with neostigmine 3.5 mg and glycopyrronium 0.8 mg. Spontaneous respiration returned, but the patient was unable to follow commands. She was therefore transported to the postanaesthesia care unit (PACU) with the tracheal tube still in place.

Shortly after arriving in the PACU, the patient became alert and attempted to extubate herself. In an effort to rapidly deflate the tracheal tube cuff, the pilot balloon and valve assembly was pulled off the pilot tube. In this process, the pilot tube was stretched, occluding the stump of the tube which was still attached to the inflated cuff, so that the tracheal tube could not be removed. The patient was verbally reassured and continued to breathe easily through the tracheal tube. Throughout this period, the patient's oxygen saturation and haemodynamic parameters were stable. On direct laryngoscopy, which was tolerated without anaesthesia, the tracheal tube was clearly seen with the inflated cuff below the vocal cords. Subsequently a 25 gauge needle on a 1 ml syringe was inserted into the pilot tube, and air was withdrawn from the tracheal tube cuff. The patient was extubated easily and subsequently made an uneventful recovery from anaesthesia.

Discussion

In the present case, the difficult extubation resulted from the failure of the tracheal tube cuff to deflate after removal of the pilot balloon and valve assembly. It was determined that the cuff could not deflate because the pilot tube had been occluded by stretching during removal of the valve and balloon assembly. Deflation of the cuff was eventually accomplished using a syringe and needle inserted past the occlusion in the stump of the pilot tube. Had we been unable to deflate the cuff by this means, other options were available, including the use of a needle to puncture the cuff, either during direct observation using a laryngoscope or through the cricothyroid membrane, or by simply cutting the pilot tube proximal to the obstruction.

The aetiology of difficult extubation is diverse. Tracheal tubes have been inadvertently wired to facial bones [1],

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sutured to the pulmonary artery [2], transfixed by a screw or broken drill bit [3], possibly adhered to the tracheal mucosa because of absence of lubricant [4], entangled with nasogastric tubes [5], and stuck below the cords by folds in the deflated cuff [6, 7]. A tracheal tube with a self-inflating spongy cuff became trapped when the cuff tube broke off at its junction with the tracheal tube, preventing deflation [8]. This report, however, is the first to present a complication at extubation directly attributable to the increasingly common practice of pulling off the pilot balloon and valve assembly in order to deflate the tracheal cuff. The justification for this appears to be related to difficulty in quickly locating a syringe with which to deflate the cuff. This practice, however, should be strongly discouraged, but not simply because of the possible occurrence of the complication reported here. Should the need arise to rapidly reintubate a recently extubated patient, it is important to have a fully functional tracheal tube of the correct size at hand. If cuff function has been destroyed during extubation, then the option of re-using the existing tracheal tube is lost.

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Anaesthesia, 1992, Volume 47, pages 231–233

CASE REPORT

The use of propofol and alfentanil by infusion in military anaesthesia

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Summary

A total intravenous technique using propofol and alfentanil was used successfully in four battlefield casualties treated at a British Military Field Hospital during the recent Gulf conflict. All patients made a rapid recovery of adequate quality for prompt evacuation. We believe that the use of propofol and alfentanil as an induction and maintenance regimen for military anaesthesia merits further evaluation and comparison with established techniques.

Key words

Anaesthesia; military.
Anaesthetics, intravenous; propofol.
Analgesics; alfentanil.

Techniques used for anaesthetising military casualties should allow many patients to undergo surgery with limited recovery facilities. Under such constraints a prompt and full recovery from the effects of anaesthesia are even more desirable than in usual civilian practice. In addition, modern warfare may be fast moving making it necessary to evacuate patients almost immediately after surgery.

Until recently, the British Army has based its anaesthetic techniques predominantly on halothane and trichloroethylene delivered by the Triservice Apparatus [1]. As trichloroethylene is no longer manufactured, interest has turned to the use of newer inhalational agents, particularly isoflurane [2, 3], and to total intravenous anaesthesia using mixtures of ketamine and midazolam [4]; or a combination of inhalational and intravenous techniques [5].

The use of propofol for military anaesthesia has not been explored to date despite propofol's widespread use for induction and maintenance by infusion [6, 7], and its speed and quality of recovery [7–9]. Alfentanil has similar features and military anaesthetists have used it in combination with ketamine and midazolam [5].

This is a report of the use in the field of propofol and alfentanil by continuous infusion in four patients with varying battle injuries inflicted during the recent Gulf conflict.

Case histories

The injuries suffered by all patients are summarised in Table 1. Morphine 10 mg and atropine 0.6 mg were given intramuscularly 1 h before operation in cases 1 and 4. As parenteral analgesics had been given to cases 2 and 3 earlier in the medical evacuation chain, premedication was omitted in these patients. All patients were fully resuscitated pre-operatively in accordance with the military medical plan, and, as a result, none were hypotensive prior to induction of anaesthesia.

Anaesthesia was induced with alfentanil 10 μg.kg^{-1} (body weights were estimated using height–weight charts) followed by propofol titrated to loss of eyelash reflex. Intubation was facilitated with suxamethonium 1 mg.kg^{-1}, except for case 4 where vecuronium 0.1 mg.kg^{-1} was used. Muscle relaxation was maintained with boluses of vecuronium and monitored using train-of-four nerve stimulation. The lungs of all patients were ventilated using Cape TC50 ventilators delivering oxygen-enriched air (inspired oxygen concentration of approximately 30%).

Anaesthesia was maintained with a combined infusion of propofol and alfentanil (2.5 mg alfentanil added to 500 mg propofol) delivered by an Ohmeda 9000 syringe pump. The infusion rate was initially set at 10 mg.kg^{-1}.h^{-1} for the first 10 min, then adjusted to perceived patient requirements, aiming for a final infusion rate of 5 mg.kg^{-1}.h^{-1}. Table 1 gives details of the doses of propofol used.

At the end of the procedure, residual paralysis was reversed with neostigmine 2.5 mg and glycopyrrolium 0.5 mg and the infusion was discontinued.

The heart rate, blood pressure and oxygen saturation were monitored throughout. Values before induction and 1, 2 and 5 min after induction were recorded and are shown in

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Table 1. Details of injuries, operative procedure and its duration, and propofol dosage.

Case	Injuries	Operation	Duration (min)	Propofol doses Induction (mg)	Infusion ($mg.kg^{-1}.h^{-1}$)
1	Traumatic avulsion of four teeth and facial lacerations	Exploration and repair	50	200	10.8
2	Traumatic amputation of foot	Debridement	78	110	5.4
3	Eye injuries, facial lacerations, compound fractures of both lower legs and amputation of both feet	Debridement of wounds, exploration of eye and external fracture fixation	163	40	3.8
4	Shrapnel wounds to leg	Debridement	30	160	7.0

Table 2. To assess recovery, the time was noted from the end of the infusion to rejection of airway, eye opening and response to command. These times are shown in Table 3.

All four patients made a good recovery from their anaesthetic and no adverse effects attributable to the anaesthetic were noted.

Discussion

There are several points of interest for military anaesthetists in these case reports. The quality and rapidity of the recovery phase using propofol and alfentanil make it a highly suitable choice of anaesthetic when compared to inhalational anaesthesia or total intravenous regimens, such as ketamine and midazolam [4]. In chemical warfare, operating theatre pollution precludes the use of inhalational agents, and while ketamine has been favoured by military anaesthetists because of the stimulatory effects on the cardiovascular system, the high incidence of emergence delirium, although largely obtunded by the addition of midazolam, may be a notable problem where there are mass casualties. Disinhibited behaviour after propofol has been reported but is benign in nature [10]. In addition, the speed of recovery after ketamine may be unpredictable, it is an unsuitable drug for use in patients with head injuries and there is a higher incidence of nausea and vomiting in recovery when compared to propofol [11, 12].

The cardiovascular depressant effects of propofol may have limited its use in trauma patients in the past; apart from the second case where a relative overdose produced transient hypotension lasting less than 1 min, no other adverse cardiovascular effects were noted. Indeed, the third patient, who was probably the most severely injured, demonstrated that this infusion regimen can be used with safety. It is emphasised that all patients underwent careful resuscitation before anaesthesia; this should, in any case, be standard practice in all settings, where clinical needs and time permit.

In practical terms, the infusion is simple to prepare and use; it merely requires the addition of alfentanil to standard strength propofol. Infusion rates were calculated without difficulty and provided a satisfactory and easily adjustable level of anaesthesia.

Where the threat of chemical warfare exists, service personnel may be given prophylactic anticholinesterase treatment; theoretically this may cause unpredictable neuromuscular blockade where muscle relaxants are used. In practice, the authors have no knowledge of any cases of abnormal sensitivity to muscle relaxants or problems with their reversal. The use of vecuronium with train-of-four monitoring proved satisfactory (the storage characteristics of atracurium make it unsuitable for use in the field).

Inhalational anaesthesia using the Triservice apparatus in its most basic form has the advantage of not relying on electricity. However, the modern field hospital has an integral generator-driven electricity supply, which should

Table 2. Heart rate (HR), blood pressure (BP) and oxygen saturation (Sp_{O_2}) following induction.

	Before induction	1 min	2 min	5 min
Case 1				
HR; $beats.min^{-1}$	84	78	102	80
BP; mmHg	129/64	185/86	149/107	127/83
Sp_{O_2}; %	98	98	98	98
Case 2				
HR; $beats.min^{-1}$	102	117	117	109
BP; mmHg	164/86	53/41	105/46	122/60
Sp_{O_2}; %	97	97	99	99
Case 3				
HR; $beats.min^{-1}$	93	76	89	85
BP; mmHg	140/80	141/69	124/84	128/69
Sp_{O_2}; %	97	99	99	99
Case 4				
HR; $beats.min^{-1}$	110	113	115	98
BP; mmHg	113/72	104/69	119/73	101/62
Sp_{O_2}; %	97	99	99	98

Table 3. Time from end of infusion to airway rejection, eye opening and response to commands (min.)

	Airway rejection	Eye opening	Respose to command
Case 1	8:00	9:00	10:00
Case 2	7:30	7:30	7:40
Case 3	8:30	8:50	10:30
Case 4	3:40	3:30	3:25

continue to function in all but the most desperate conditions. Conversion from an infusion technique to an inhalational, hand-ventilated anaesthetic would be straightforward. This is not a major disadvantage when compared to the loss of theatre lighting, suction, monitoring and automatic ventilation, which would occur in the same situation.

Fortunately, the casualty rates in the Gulf conflict were much lower than had been anticipated, therefore it is not possible to infer too much about a particular anaesthetic technique from a few case reports. However, these cases suggest that a comparative trial under field conditions between propofol and alfentanil and the established ketamine and midazolam regimen would be worthwhile, and that this technique may well have a place in the military anaesthetist's future armamentarium.

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Anaesthesia, 1992, Volume 47, pages 234–236

CASE REPORT

Pituitary apoplexy following cholecystectomy

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Summary

A case of pituitary apoplexy, which presented with hyperaesthesia in the distribution of the ophthalmic division of the left trigeminal nerve and a left sixth nerve palsy following cholecystectomy, is reported. Computed tomography and magnetic resonance imaging revealed a large intrasellar mass which extended laterally into the left cavernous sinus and showed evidence of old and recent haemorrhage within the tumour. This case demonstrates that patients who present with unusual neurological symptoms involving the cranial nerves after general anaesthesia, should undergo neurological and radiological investigations.

Key words

Brain; pituitary apoplexy.
Surgery; cholecystectomy.
Complications; neurological.

Pituitary apoplexy is a rare clinical syndrome caused by the sudden enlargement of a pituitary adenoma secondary to infarction or haemorrhage. It is characterised by the sudden onset of headache, ocular palsies, visual disturbances, and an altered state of consciousness and is life-threatening if untreated. Although the exact pathophysiology of its development is not known, some predisposing factors such as sudden trauma, anticoagulation, alteration of cerebrovascular pressure gradients, diabetic ketoacidosis, oestrogen or bromocriptine therapy, angiography, and radiotherapy have been suggested [1–3]. Although pituitary apoplexy has been reported following coronary artery bypass surgery [4], there have been no convincing reports of its occurrence after noncardiac surgery.

We report a case of pituitary apoplexy which presented with a left sixth nerve palsy and supra-orbital neuralgia after cholecystectomy, which was performed under a combination of general anaesthesia and epidural analgesia.

Case history

A 47-year-old man was admitted for a cholecystectomy for asymptomatic cholelithiasis, which was discovered at a clinical survey. His past medical history was unremarkable except for a 2-year history of oedema of the legs of unknown origin. Physical examination and laboratory investigations, including endocrinological examination, showed no other abnormalities.

An epidural catheter was inserted without difficulty. After uneventful induction of general anaesthesia with thiopentone 300 mg and midazolam 10 mg, anaesthesia was maintained with 67% nitrous oxide in oxygen, and 1% carbocaine 15 ml was given through the epidural catheter. Three further injections of 1% carbocaine 5 ml were given over the 3 h period of surgery. Cardiovascular and respiratory parameters remained normal apart from a decrease in systolic blood pressure of about 30% of the pre-induction value following the third epidural injection, which was treatment with methoxamine 3 mg. Surgery and anaesthesia were otherwise uneventful. The patient's only complaint in the recovery period was that of pain on the left side of his forehead. The next day he complained of double vision in addition, and neurological examination revealed hyperaesthesia affecting the ophthalmic division of the left trigeminal nerve and a left sixth nerve palsy. A local anaesthetic block of the left supraorbital nerve completely abolished the pain in his forehead, but the sixth nerve palsy persisted. Computed tomography (CT) showed a large intrasellar mass with lateral extension into the left cavernous sinus (Fig. 1). Magnetic resonance imaging (MRI) revealed old and fresh haemorrhages into the tumour (Fig. 2). Endocrinological examination showed mild hypo-

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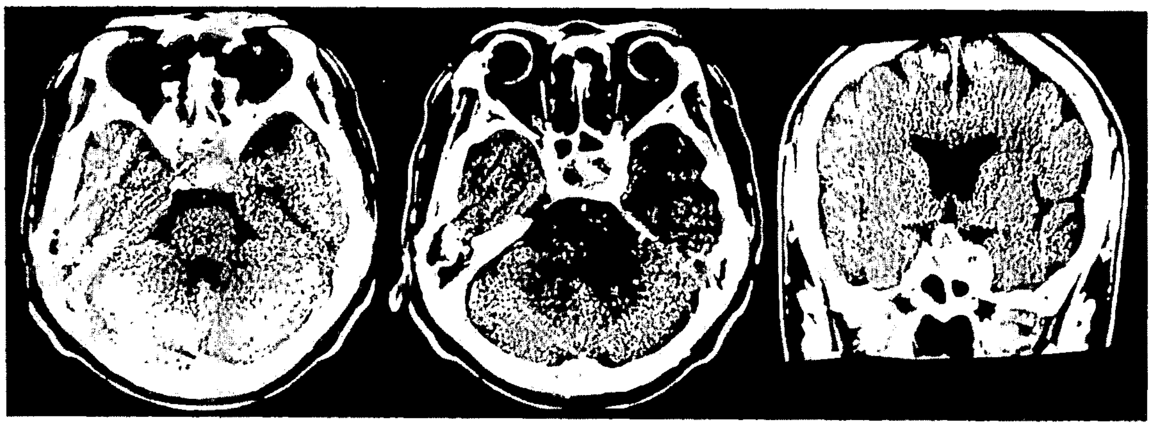

Fig. 1. Axial plain computed tomography (CT) shows an intrasellar mass which contains areas of both low and high density. The latter is consistent with fresh haemorrhage (left), and axial contrast-enhanced CT shows parasellar faint ring enhancement. This is consistent with old haemorrhage (centre). The coronal contrast-enhanced CT scan shows suprasellar extension and lateral extension into the left cavernous sinus (right).

thyroidism with a T_3 of 0.61 $ng.ml^{-1}$ (normal 0.7–2.1 $ng.ml^{-1}$) and a T_4 of 3.3 $\mu g.dl^{-1}$ (normal 4.7–11.8 $\mu g.dl^{-1}$). Trans-sphenoidal hypophysectomy, which was performed 3 weeks after the cholecystectomy, confirmed the diagnosis of pituitary apoplexy secondary to intratumoral haemorrhage.

Discussion

To our knowledge, only seven cases of pituitary apoplexy following surgery have been reported, all of which occurred after cardiopulmonary bypass [4].

The clinical diagnosis of pituitary apoplexy may be confirmed by CT scan or MRI [5]. In this case the CT and MRI suggested that the patient had had a previous asymptomatic haemorrhage into the adenoma (Figs 1 and 2). He first presented with pituitary apoplexy when lateral extension of the mass into the left cavernous sinus resulted in hyperaesthesia in the distribution of the left supraorbital nerve and a left sixth nerve palsy. In common with many previously reported cases of pituitary apoplexy, there was no suspicion of pituitary disease before the acute event [1–3,5,6]. Pituitary apoplexy may present with leakage of blood into the subarachnoid space, and this haemorrhage must be differentiated from subarachnoid haemorrhage (SAH) caused by the rupture of an intracranial aneurysm. Occasionally, intracranial aneurysms and pituitary adenomas co-exist [1] and in one such case, the subarachnoid haemorrhage which occurred was associated with the adenoma, not the aneurysm [1]. It should be noted that the time course of pituitary apoplexy is similar to that of an aneurysmal SAH, although occasionally symptoms develop slowly over several weeks [7].

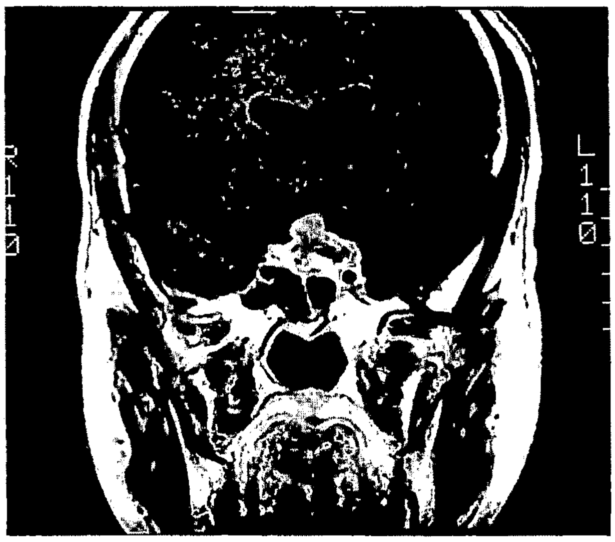

Fig. 2. Magnetic resonance imaging (MRI) reveals old and fresh intratumoral haemorrhages, and involvement of the left cavernous sinus with inferolateral displacement of the left carotid artery.

The endocrine disturbances associated with pituitary apoplexy may either be produced by the adenoma (if hormone secreting) or can result from the pituitary or hypothalamic damage secondary to the haemorrhage or infarction. Although this patient was fortunate in having only mild hypothyroidism, the haemorrhage or infarction may result in multiple pituitary hormone deficiencies, and these can contribute to morbidity and mortality [2,7]. In these cases, administration of steroids may improve the level of consciousness and reverse the systemic hypotension [7].

When impairment of cerebral function occurs after surgery, a number of predisposing factors, such as age [8], a history of cerebral vascular damage [8], disordered coagulation [9] and intracardiac thrombi [10] have been suggested. However, even in patients undergoing cardiopulmonary bypass, no association was found between intra-operative hypotension and postoperative neurological dysfunction [11,12].

There is some evidence to suggest that pituitary adenomas have a relatively compromised blood supply in that the vessel walls are thicker than the walls of the sinusoids in the normal gland. It is suggested that constriction of these abnormal vessels might lead to ischaemia, necrosis, and haemorrhage [3]. The occurrence of haemorrhage can be correlated with the size and degree of invasiveness of the tumour [3]. This has led to the suggestion that patients with large invasive pituitary adenomas are susceptible to hypotension, which could result in tumour infarction [13]. In this patient, catecholamine release in response to hypotension might have affected the cerebral blood flow [14].

In patients with pituitary adenomas, techniques which produce hypotension, or factors which increase cerebral venous pressure, such as bucking, jugular venous or abdominal compression and a positive end expiratory pressure, should be avoided [2,13,15]. However, since asymptomatic pituitary adenomas are difficult to diagnose pre-operatively [1–3,5,6], its existence is not likely to be suspected.

Nevertheless, this case does demonstrate that patients who have unusual symptoms referable to the cranial nerves after surgery should be closely observed and neurological and radiological investigations undertaken. Early diagnosis and immediate neurosurgical decompression is essential if vision is to be preserved and permanent ischaemic deficits are to be prevented [2,3,7]. The possibility of consequential hypopituitarism should also be given urgent consideration [7].

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Anaesthesia, 1992, Volume 47, pages 237–239

CASE REPORT

Fibreoptic oximetry in the diagnosis of aortocaval fistula

A case study and review of the literature

K. J. KHAN, G. M. K. TSANG, J. W. L. FIELDING AND J. F. BION

Summary

Fibreoptic oximetry was used to confirm the clinical diagnosis of aortocaval fistula which occurred in a patient with an aortic aneurysm.

Key words

Complications; aortocaval fistula.
Measurement techniques; fibreoptic oximetry.

Aortocaval fistula is an uncommon complication of abdominal aortic aneurysm. Pre-operative diagnosis is important but can be difficult. We present a case in which fibreoptic oximetry helped to confirm the clinical diagnosis.

Case history

A previously fit 78-year-old man was admitted to hospital with a 5 h history of central chest pain, numbness of the left arm, and vomiting. On subsequent enquiry his relatives said that he had also complained of feeling faint in hot environments for several months, and his general practitioner had recently been treating him for low blood pressure.

On examination he was pale, clammy, peripherally cyanosed, and had mild ankle oedema. His arterial blood pressure was 110/45 mmHg in the left arm and 90/50 mmHg in the right arm. Heart rate was 110 beat.min^{-1}, and he had a raised jugular venous pressure and an audible third heart sound. On abdominal examination he had a 6–7 cm pulsatile, slightly tender mass in the left hypochondrium and a bruit was audible all over the abdomen. His chest X ray showed bilateral basal pulmonary oedema with deviation of the trachea around the thoracic aorta. There were ischaemic changes in the anterior leads of his electrocardiogram.

The initial provisional diagnosis was an abdominal aortic aneurysm complicated by myocardial ischaemia with left ventricular failure. He was treated with intravenous diuretics and sublingual nitrate which relieved his chest pain but resulted in a decrease in blood pressure to 70/40 mmHg, returning to 90 mmHg systolic after 1 h.

Thirty-six hours after admission he complained of abdominal pain and became hypotensive with a relative bradycardia. Again a difference in blood pressure in the two arms was recorded, and it was noted that he had not passed urine all day. An extension of dissection of the abdominal aneurysm to the thoracic aorta was considered the most likely diagnosis and he was transferred to the Queen Elizabeth Medical Centre for further management. On arrival he was hypotensive (70–80 mmHg systolic) but conscious and relatively undistressed.

A limited arch aortogram was performed. This excluded an arch dissection, and he was taken to the operating theatre for repair of the abdominal aneurysm. At laparotomy 2 l of clear ascitic fluid were drained, and a large, apparently unruptured infrarenal aortic aneurysm was found. During the procedure he received dobutamine by infusion at a rate of 20 μg.kg^{-1}.min^{-1} to maintain a systolic blood pressure of 80–90 mmHg. Because of the degree of hypotension and concern about myocardial function, no further surgery was undertaken, the abdomen was closed, and he was transferred to the intensive care unit.

On arrival, an adrenaline infusion was started, and increased to a rate of 40 μg.kg^{-1}.min^{-1} to maintain a systolic blood pressure of 70–80 mmHg. He was anuric, had marked peripheral cyanosis, and appeared clinically vasoconstricted. Arterial blood gases were satisfactory. A flotation catheter was passed into the pulmonary artery to allow thermodilution measurement of cardiac output,

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Table 1. Oxygen saturations detected by an oximetric flotation catheter as it was advanced proximally from its point of entry in the femoral vein. An aortocaval fistula was identified later at the aortic bifurcation.

Distance (cm) from femoral vein puncture	Oxygen saturation (%)
10	72
15	98
20	100
30 (hepatic vein)	84
simultaneous saturation in superior vena cava	62

which was 13 $l.min^{-1}$; systemic vascular resistance was 250 $dyne.s.cm^{-5}$, central venous pressure was 22 mmHg, pulmonary artery wedge pressure was 10 mmHg, and the mixed venous oxygen saturation was 82%. Because of the discrepancy between the calculated systemic vascular resistance and the assessment of skin perfusion, together with the high mixed venous saturation, we considered the possibility of an aortocaval fistula. The diagnosis was confirmed, and the site of the fistula identified, by passing an oximetric flotation catheter via the left femoral vein into the inferior vena cava. A damped arterial waveform could be identified, maximal at 15 cm from the site of insertion. Mixed venous saturations were recorded serially as the catheter was passed proximally, and the values are shown in Table 1.

The patient was taken back to the operating theatre, where the aortocaval fistula was identified at the aortic bifurcation. An aorto-bifemoral graft was inserted. Vasoactive drug therapy was changed to dobutamine alone, and within 30 min the patient started to produce urine at a rate of 100–200 $ml.h^{-1}$. Repeat thermodilution measurement showed a cardiac output of 6 $l.min^{-1}$ and a systemic vascular resistance of 600 $dyne.s.cm^{-5}$. He went through a period of nonoliguric acute renal failure which did not require dialysis and made a gradual recovery complicated by a wound dehiscence. He was discharged home 3 weeks later.

Discussion

The symptoms and signs of myocardial decompensation were interpreted as a primary problem rather than a secondary event and resulted in a delay in reaching the correct diagnosis. The earlier use of a flotation catheter would have suggested an arteriovenous fistula as a possible cause of the discrepancy between right and left heart pressures and the high mixed venous oxygen saturation, with the high cardiac output as further evidence. The absence of detailed cardiovascular information resulted in two independent diagnoses (ischaemic myocardial failure and an abdominal aneurysm), with the first then influencing clinical judgment about the investigation and management of the second.

Aortocaval fistulae may either be spontaneous or post-traumatic. Spontaneous fistulae are more common and are usually secondary to atherosclerotic aneurysms [1] although they have been described in syphilitic aneurysms [2], Marfan's syndrome [3] and Ehlers Danlos syndrome [4]. The first spontaneous aortocaval fistula (ACF) was described by James Syme in 1831 [5]. Since then over 100 cases have been reported with the first successful surgical repair by Cooley in 1954 [6]. ACF is a rare complication of aortic aneurysm and is found in less than 1% of all patients who undergo surgery for aneurysm repair, and 3% of ruptured aneurysms. The usual site of the fistula is between distal aorta and inferior vena cava [7]. Post-traumatic fistulae account for 10–20% of cases [8] and may follow penetrating injury or intervertebral disc surgery.

The pre-operative diagnosis of ACF is made in 20% or less of cases [9], for several reasons. In view of the comparative rarity of ACF, clinical suspicion may not be aroused. The fistula may be obstructed by aneurysmal mural thrombus and hence not be patent, and the signs of ACF may therefore be absent. Even when the fistula is patent, 20% of patients do not present with the classical triad of abdominal and back pain, a palpable aneurysm and a bruit [10]; in some cases, heart failure or myocardial ischaemia [11], renal failure [12] and haematuria [13] may be the presenting features. However, a pre-operative diagnosis is important for peri-operative management and outcome.

An ACF is often diagnosed as either a leaking or ruptured aortic aneurysm; up to 40% exist concurrently [9]. The ACF causes a hyperdynamic circulation with high right atrial pressures, and the patient may appear to be in better clinical condition than might be expected from the degree of hypotension. High-output cardiac failure may be the presenting feature and may be made worse by rapid pre-operative fluid replacement [10]. A pulmonary artery flotation catheter is the best method of monitoring circulating volume [14]. An adequate arterial blood pressure is difficult to maintain in the presence of an anatomical shunt; if the low systemic vascular resistance is managed with vasoconstrictors, blood pressure is maintained at the expense of tissue perfusion. Diagnosis of the fistula and its site is particularly important because when the proximal aorta is clamped and the aneurysmal sac opened, torrential venous bleeding may occur; both surgeon and anaesthetist must be prepared for substantial blood loss. Gentle clamping of the aneurysmal neck may be necessary to avoid a sudden increase in afterload to an already volume-overloaded myocardium [15]. The inferior vena cava should be clamped both below the fistula to control venous bleeding, and above to prevent pulmonary embolism of aneurysmal mural thrombus through the fistula [16]. In a report of six acute aortocaval fistulae [12], balloon tamponade was found to be useful in three cases to control venous haemorrhage. The balloons were positioned through the aortic sac in one, and transvenously in the other two.

Once clinical suspicion has been aroused, the diagnosis may be confirmed and the fistula localised by aortography [17], currently the definitive diagnostic procedure [18]. However, other noninvasive methods such as computed tomography (CT) [19], magnetic resonance imaging [18] and echo Doppler [20] have been used. All these methods depend upon a patent ACF. Aortography is time consuming because the exact site of the fistula must be identified. CT may be used to demonstrate aortic and vena caval dilatation; on dynamic scanning the rapid flow of contrast medium from the arterial side into the dilated vena cava is characteristic of a fistula. However, the precise site of the fistula may not be shown. There has been one report of the use of fibreoptic oximetry to confirm the diagnosis of an ACF [21] in a patient with a dissecting aneurysm of the ascending aorta which had ruptured into the superior vena cava; the oximetry probe was introduced via the internal jugular vein. There are no previous reports of its use to diagnose the more common abdominal ACF. However, in one case report [20], echo Doppler suggested an ACF, the exact site of which was then confirmed by descending aortogram and intermittent oximetry. The technique of percutaneous cannulation of the femoral vein and continuous oximetry is simple, quick and relatively inexpensive, does not involve moving a critically ill patient to the radiology department, and confirms both the diagnosis and the site of a patent fistula by demonstrating an arterial waveform and a rise in oxygen saturation as the fistula is approached.

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SPECIAL ARTICLE

Magnetic resonance for the anaesthetist

Part I: physical principles, applications, safety aspects

D. K. MENON, C. J. PEDEN, A. S. HALL, J. SARGENTONI AND J. G. WHITWAM

Summary

Anaesthetists are being increasingly involved in magnetic resonance (MR) procedures, both in patient care and as a research tool. This paper outlines the physical basis of nuclear magnetic resonance and describes its application in magnetic resonance imaging and spectroscopy. Principles of magnet design and safety relevant to anaesthetic practice in a magnetic resonance environment are discussed and guidelines for anaesthetic practice suggested. Some recent clinical magnetic resonance studies of anaesthetic interest are reviewed.

Key words

Measurement techniques; nuclear magnetic resonance, magnetic resonance imaging, magnetic resonance spectroscopy.

Nuclear magnetic resonance (NMR) is a phenomenon that was first described by Bloch and Purcell in 1945, and the technique was widely used as an analytical tool in chemistry and biochemistry in the following decades. In 1973, Lauterbur and his associates published the first application of NMR to imaging, and laid the foundations of what proved to be an important medical imaging tool. This application of NMR to imaging came to be known as magnetic resonance imaging (MRI), the 'nuclear' in NMR being removed to emphasise that this technique was unassociated with any radiation risk. By analogy, the application of NMR to chemical and biochemical analysis has come to be termed magnetic resonance spectroscopy (MRS). At present, MRI is the imaging modality of choice in the diagnosis of many neurological and orthopaedic conditions, and MRS has been widely used for research and may soon acquire a diagnostic role. There are more than 2500 MR installations in the USA, and though there are still only about 50 modern MR units in the UK, this number is likely to rise, and anaesthetists may find themselves increasingly involved in patient care and research in MR. It is important, therefore, that anaesthetists acquire an understanding of the technique and familiarity with patient management in an MR environment. This paper is based on the knowledge and experience acquired over 2 years in a research MR site at the Hammersmith Hospital, and is in two parts. In Part I we explain the physical basis of NMR, outline its application to spectroscopy and imaging, and discuss the safety of MR procedures. Part II

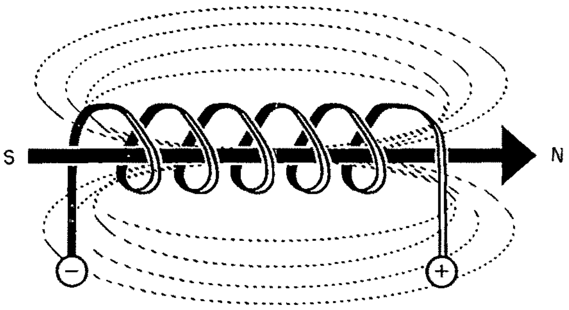

Fig. 1. Diagrammatic representation of current flowing through a coil and producing an electromagnetic field. N and S in this and subsequent diagrams represent the north and south poles of the magnet.

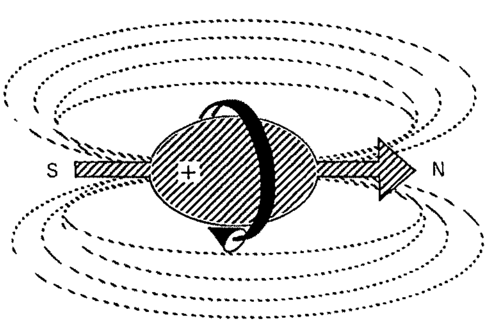

Fig. 2. Diagrammatic representation of a spinning atomic nucleus. Movement of the positively charged protons produces a magnetic field, causing the nucleus to behave like a baby bar magnet.

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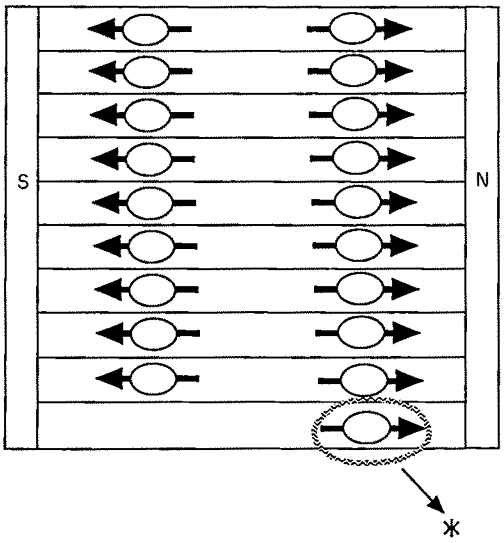

Fig. 3. Diagrammatic representation of NMR-sensitive nuclei aligned in a magnetic field. Nuclei are aligned either parallel or antiparallel to the field. A small excess of nuclei (1–2/10^6) are parallel to the field (*), and are responsible for the NMR phenomenon.

deals with monitoring systems and anaesthetic practice in MR environments.

This discussion of the principles of NMR uses a combination of quantum and classical physics, and attempts to simplify what is a complex phenomenon. In the interest of clarity, some detail is necessarily lost, and readers looking for a more comprehensive description are referred elsewhere [1].

Physical principles

The basis of nuclear magnetism

All atomic nuclei possess a charge (due to the presence of protons) and mass (due to the presence of protons and neutrons). In addition, the nuclei of some atoms possess a spin, a property that may be visualised as a rotation of the nucleus about its own axis. Just as the flow of electrons in a wire loop produces an electromagnetic field (Fig. 1), the rotation of neutrons and protons in a spinning nucleus produces a local magnetic field (Fig. 2). As a result the nucleus behaves like a miniature bar magnet. This nuclear magnetism is many times weaker than the common magnetism with which we are familiar (and which is a property of electrons).

Behaviour of NMR sensitive nuclei in a magnetic field

When NMR sensitive nuclei are placed in a powerful static magnetic field (referred to as the B_0 field), they tend to align themselves longitudinally with the field (along an axis arbitrarily designated as 'Z'). Approximately one half of the nuclei are aligned parallel to the field and the other half antiparallel to it (Fig. 3). There is a small excess of nuclei in the lower energy parallel state, and a small net magnetisation parallel to the B_0 field. It is this small excess of nuclei in the parallel state (typically of the order of 1–2/10^6) that are of interest and form the subject of the remainder of this discussion. Since such a small proportion of available nuclei are responsible for the NMR phenomenon, and since the energy transitions involved are small, magnetic resonance is basically an insensitive technique, and can only be used to study substances that are present in at least millimolar concentrations.

The resonant frequency of a nucleus and its determinants

When aligned with the field, the nuclei continue to spin, and at the same time their axis of rotation rotates around the Z axis. This combination of movements is termed precession, and is a process that is best exemplified by the movement of a spinning top in the earth's gravitational field (Fig. 4). The frequency of nuclear precession (ν) depends on two variables: the gyromagnetic ratio (γ), which is specific for each nucleus, and the strength of the magnetic field (B_0):

$$\nu = \gamma . B_0/2\pi \qquad (1)$$

Thus, each nucleus has a characteristic or resonant frequency at a given magnetic field strength. The specificity of this frequency enables the selection of a particular nucleus for study.

Excitation of nuclei by a second magnetic field and the production of NMR signal

When such a population of nuclei is intermittently subjected to a second magnetic field (B_1), oscillating at the resonant frequency of the nucleus, and orientated at right angles to the static field (B_0), they tend to flip away from their longitudinal alignment and produce magnetisation in

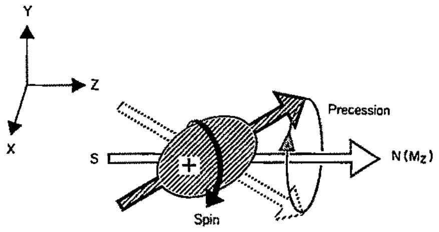

Fig. 4. Movement of an NMR-sensitive nucleus in a magnetic field. The nucleus spins on its own axis, and precesses about the magnetic axis.

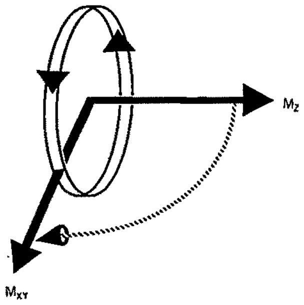

Fig. 5. Application of an oscillating (B_1) field causes the magnetisation along 'Z' to flip into the XY plane, where it continues to precess around the Z axis.

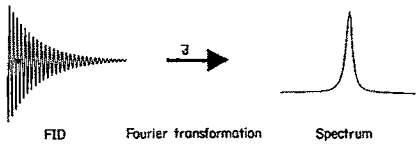

Fig. 6. The decaying sinusoidal waveform on the left is the free induction decay (FID) and represents the current induced in a copper wire placed in the vicinity of an excited nucleus (as in Fig. 5). Fourier transformation of the FID (ℑ) results in a spectrum where intensity is plotted against frequency.

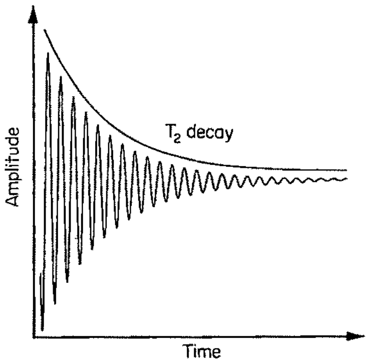

Fig. 7. Diagrammatic representation of the decay of an FID, which is characterised by the spin–spin relaxation time constant (T_2).

a plane at right angles to the Z axis (the XY plane) (Fig. 5). This magnetisation in the XY plane is still precessing around the Z axis, and decays with time after each exciting pulse. A stationary wire in the presence of such a changing magnetic field has a current induced within it. This current has a decaying sinusoidal waveform (Fig. 6), whose frequency is the same as the frequency of nuclear precession, the resonant frequency (ν).

This current is related to the NMR signal and is graphically represented as the Free Induction Decay (FID), which is a plot of signal intensity against time. The FID can be subjected to a process termed Fourier Transformation to produce a spectrum, where signal intensity is plotted against signal frequency (Fig. 6). Thus, the Fournier Transform (FT) process relates signal in the time and frequency domains. When the nucleus being studied is present in very small concentrations ($\approx$ 1 millimolar), several free induction decays may need to be averaged to produce a spectrum with useful amounts of signal in relation to the background noise.

Relaxation time constants (T_1 and T_2)

The decay of transverse magnetisation with time is described by a time constant termed the spin–spin relaxation time constant or T_2 (Fig. 7). Thus, when T_2 is large the signal tends to decay more slowly. It is important to note that T_2 can be used to provide a measure of the mobility of the environment of a given nucleus, generally increasing with increasing molecular mobility, and decreasing with molecular restriction. In practice, the time frame of most biologically significant NMR experiments means that we tend to see signals that arise predominantly from small mobile molecules, since the signal from larger molecules has a very short T_2 (i.e. decays very rapidly) and usually goes undetected.

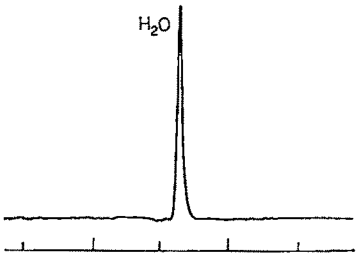

Fig. 9. Proton spectrum of water. All the protons are in a similar chemical environment and produce a single resonance.

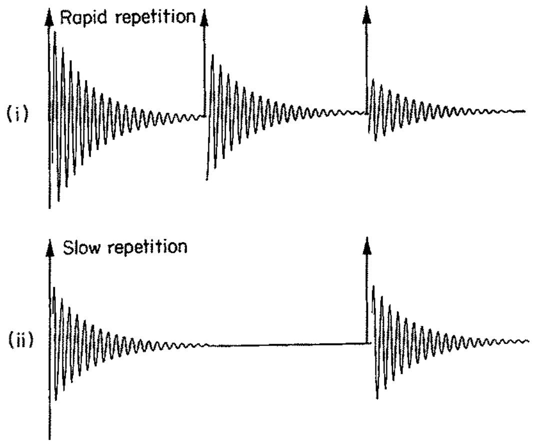

Fig. 8. Effect of repetition time (TR) on signal levels. Successive excitations are denoted by vertical arrows. In (i) the TR is short, recovery of magnetisation between successive pulses is incomplete and signal from successive pulses is attenuated. In (ii) the long TR allows complete recovery of magnetisation and signal strength is maintained with successive pulses.

Each time the longitudinal magnetisation along the Z axis is flipped into the XY plane, it takes a finite amount of time to recover to basal levels. This process of recovery of longitudinal magnetisation can be characterised by another time constant, termed the spin–lattice relaxation time constant or T_1. If the time between successive excitations is short, nuclei with a long T_1 will recover incompletely between excitations, resulting in decreasing amounts of NMR signal, a process termed saturation (Fig. 8).

Chemical implications and biochemical applications

Effects of chemical structure on resonant frequency: the chemical shift (δ)

It is clear from the above discussion that the frequency of a given signal depends on the nucleus being studied and the strength of the magnetic field that it is in. What makes NMR useful as a chemical tool is the fact that the magnetic field surrounding a given nucleus is subtly modified by the atoms that surround it, resulting in a change in resonant frequency with changing chemical composition. Thus, the proton (or hydrogen) spectrum from water consists of a single line because the two hydrogen nuclei within each H_2O molecule have the same chemical environment (Fig. 9). The proton spectrum from acetic acid, on the other hand (Fig. 10), shows two peaks, each from protons in a unique chemical environment. The position of each

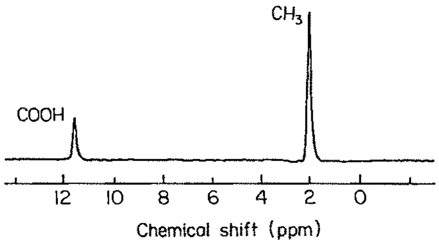

Fig. 10. Proton spectrum of acetic acid. Protons in the methyl (CH_3) group are in a different chemical environment from those in the carboxyl (–COOH) group, resulting in two separate resonances. Since there are three times as many methyl as carboxyl protons, the CH_3 resonance is three times the intensity of the –COOH resonance.

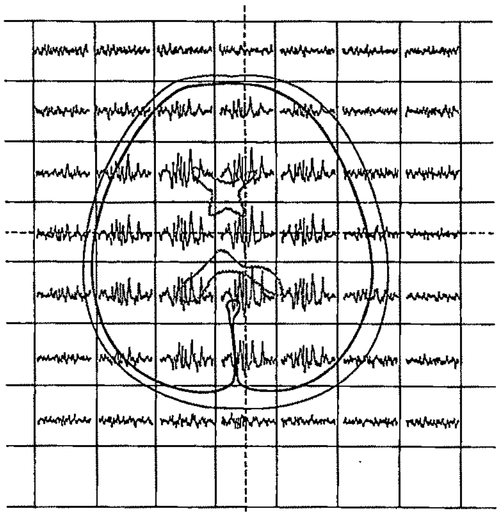

Fig. 11. One plane from a ^{31}P four-dimensional chemical shift image of the brain. ^{31}P MR spectra are simultaneously acquired from multiple voxels whose spatial location is shown above on an outline of a transverse image of the brain.

peak on the horizontal axis can be expressed as its displacement from the resonant frequency in Hertz, but is more often expressed as its displacement from the resonance of an internal or external reference compound, and is termed its chemical shift. The chemical shift (δ) is usually expressed as parts per million (ppm) of the reference frequency, an arrangement that enables comparison of chemical shifts at different field strengths. An inspection of Fig. 10 also shows that the height of each peak is related to the number of protons contributing to a particular resonance. Thus NMR, in the form of magnetic resonance spectroscopy, can provide quantitative chemical information. This application of NMR has been used *in vitro* by chemists and biochemists for many decades. What makes MRS especially useful is the fact that the phenomenon can be studied *in vivo*, thus providing what is a nondestructive, noninterventional, repeatable and nonhazardous method of acquiring chemical and biochemical information from living tissues.

Recent advances have also enabled the localisation of these signals to specific volume elements (or voxels); among the most advanced forms of such localisation is the four-dimensional chemical shift imaging (CSI) technique illustrated in Fig. 11, where a matrix of 512 voxels of 8 ml volume can be simultaneously sampled to yield spectroscopic information [2].

Table 1. NMR sensitive nuclei of biological interest.

Nucleus	NMR frequency (MHz)*	Natural abundance (%)	Relative sensitivity at natural abundance
Protons (^{1}H)	100.00	99.98	100.0
Fluorine (^{19}F)	94.08	100.00	83.3
Phosphorus (^{31}P)	40.48	100.00	6.6
Carbon (^{13}C)	25.14	1.11	0.02
Sodium (^{23}Na)	26.45	100.00	9.2

*Frequencies are arbitrarily assigned at a field strength of 2.35 tesla, chosen such that the resonant frequency for protons (^{1}H) is 100 MHz.

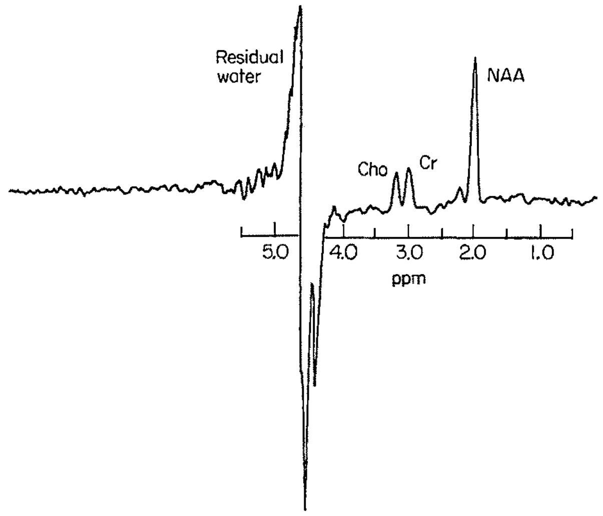

Fig. 12. Proton spectrum of the brain acquired from a 8 ml voxel in the parietal region of a volunteer. The complex resonance on the left arises from tissue water that has been suppressed by a factor of about 200 in order to allow visualisation of the metabolites. Abbreviations as in text.

NMR sensitive nuclei of medical/biological interest

The nuclei that exhibit the NMR phenomenon and are of biological interest are listed in Table 1. As the table suggests, the usefulness of each of these nuclei depends on several factors, including its relative sensitivity (which depends on the gyromagnetic ratio of the nucleus and its natural abundance) and its biological importance. For purposes of comparison, the hydrogen nucleus is assigned a sensitivity of 100, and all other nuclei are compared against it. We shall now consider each of these nuclei in turn.

Hydrogen (Protons, ^{1}H)

This is the most sensitive of the biologically significant nuclei, and is present in a wide variety of compounds. Body water contains approximately 100 molar ^{1}H, and this high concentration provides the signal that is used for MR imaging. Prominent signals are also observed from fat. *In vivo* ^{1}H spectroscopy however, is hampered by these high proton concentrations since hardware currently in use is swamped by the signal and does not possess the dynamic range needed to study simultaneously metabolites that are only present in millimolar concentrations. ^{1}H spectroscopy therefore, requires the suppression of the massive water signal, which may be technically difficult to achieve. Most clinical ^{1}H MRS has concentrated on the brain, where a number of metabolites can be seen [3] (Fig. 12). These include N-acetyl aspartate (NAA), which seems to be a metabolic marker for normally functioning neurons, and signals from creatine and phosphocreatine (Cr), and from choline containing compounds (Cho), which are chiefly liquid substrates. Signals are also obtainable from other important metabolites such as lactate, glutamine, glutamate, taurine and inositols.

Phosphorus-31 (^{31}P)

This is a relatively insensitive nucleus, but the NMR visible isotope (^{31}P) does form the bulk of naturally occurring phosphorus. Many biologically important compounds

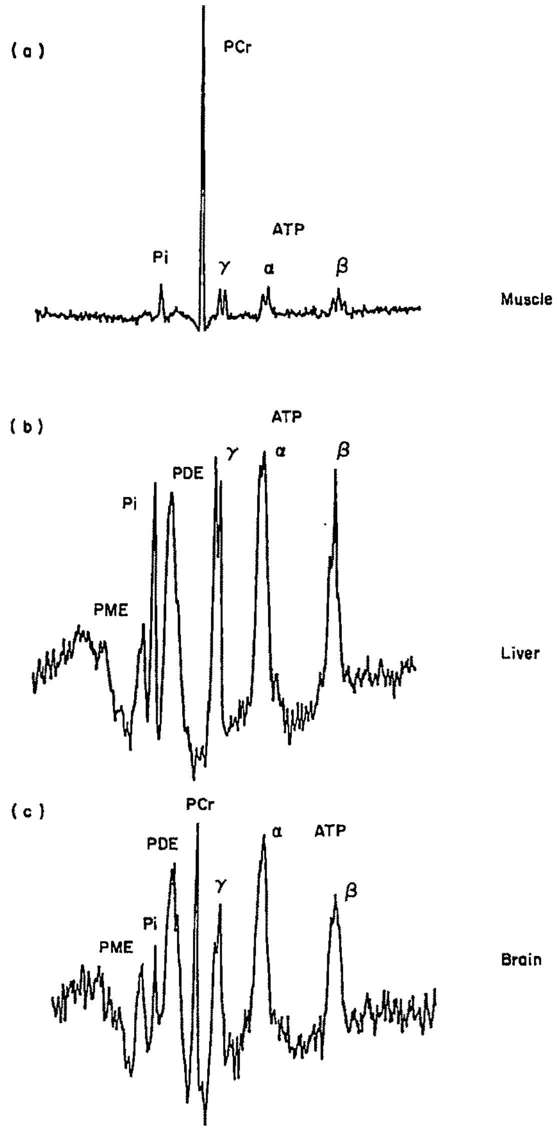

Fig. 13. ^{31}P MR spectra of normal (a) muscle, (b) liver, (c) brain. Abbreviations as in text.

contain phosphorus, and early *in vivo* MR spectra produced from experimental animals and man utilised the ^{31}P nucleus [4, 5]. ^{31}P MR spectra provide a variety of information.

1. *Energy metabolism:* ^{31}P MR spectra from muscle and brain show prominent resonances from the three phosphate groups of adenosine triphosphate (ATP) and from phosphocreatine (PCr) while spectra from the liver contain resonances from ATP but not from PCr (Fig. 13). Both ATP and PCr are compounds that store high energy phosphate residues, and utilisation of the stored energy produces inorganic phosphate (Pi) which exhibits a separate resonance. Thus the ratios Pi/PCr and Pi/ATP provide some measure of the energy state of the cell [1] (Fig. 14).

2. *Intracellular pH (pHi):* The majority of the Pi seen in the ^{31}P spectra is intracellular and exists in two forms (HPO_4^{3-} and $H_2PO_4^{2-}$) which are in equilibrium, with relative concentrations depending on the pHi. Changes in pHi alter the relative concentrations of the two components and hence their relative effect on the position of the peak. The Pi peak is extremely sensitive to pH changes, tending to move to the right in acidosis and to the left in alkalosis, and its position can be used to measure absolute levels and relative changes of pHi (Fig. 14) with an accuracy of about 0.1 pH units [6].

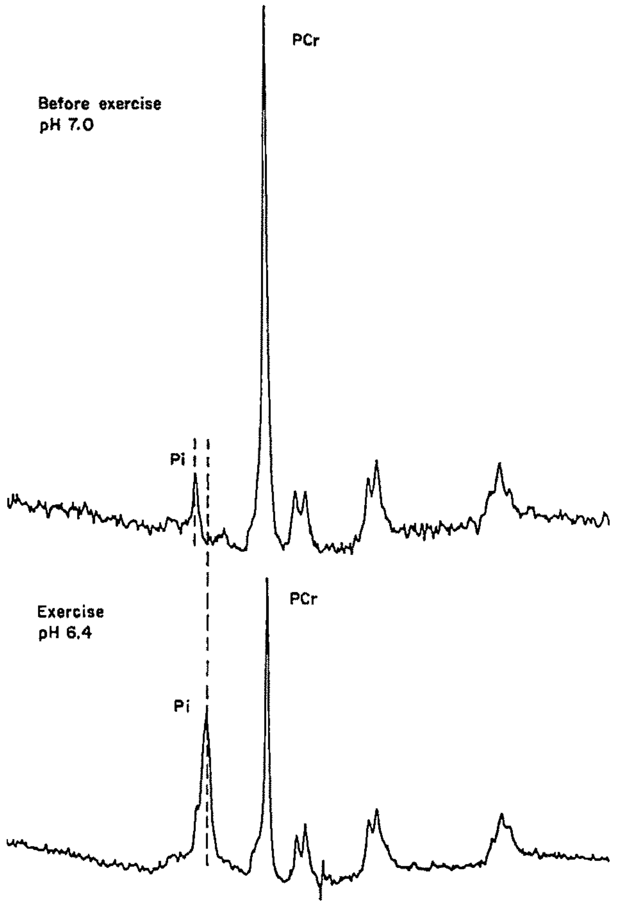

Fig. 14. ^{31}P MR spectra of normal calf muscle, (a) at rest and (b) during exercise. Note the reduction in the PCr/Pi ratio and the rightward shift of the Pi resonance with exercise. The shift of the Pi resonance is due to a fall in muscle pHi.

3. *Phospholipid metabolism:* The resonances to the left and right of the Pi peak are termed the phosphomonoester (PME) and phosphodiester (PDE) peaks respectively. Both peaks contain contributions from more than one compound. Principally, the PME peak contains contributions from precursors of phospholipid synthesis, while products of phospholipid degradation contribute to the PDE peak. In ^{31}P spectra from the liver, the PDE peak may also contain contributions from phospholipid headgroups in endoplasmic reticulum [7]. Thus, inspection of these peaks can provide us with information regarding membrane phospholipid metabolism. The PME peak in spectra from all organs may also contain contributions from glycolytic intermediates such as glucose 6-phosphate.

Carbon (^{13}C)

Though carbon is present in most compounds within the human body, its most abundant isotope, ^{12}C, does not exhibit NMR properties, and ^{13}C, which is NMR visible, is a relatively insensitive nucleus, and constitutes less than 0.1% of naturally occurring carbon. Naturally occurring ^{13}C is present in adequate concentrations for *in vivo* MRS only in substances like glycogen and lipid [8]. However,

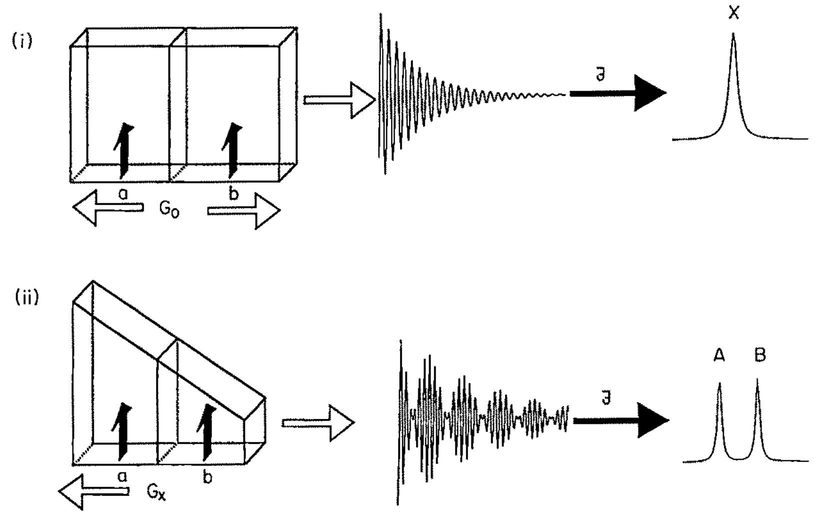

Fig. 15. Principles of spatial localisation using magnetic field gradients. In (i) the magnetic field is uniform and objects (a) and (b) experience the same field strength, and consequently produce a single resonance (X). In (ii) there is a gradient in the magnetic field (G_x). Object (a) experiences a higher magnetic field than object (b) resulting in two separate resonances (A) and (B). This difference in frequency thus encodes spatial information in the spectrum.

labelled molecules containing the stable isotope ^{13}C can be used in tracer studies, and provide an exiting means of charting metabolic paths *in vivo*. A word of caution. ^{13}C labelled compounds are extremely expensive and a single human study may cost several hundred pounds.

Fluorine (^{19}F)

There are no fluorine containing compounds present naturally that contain quantities of MR visible ^{19}F in concentrations that can be studied by *in vivo* MRS. However ^{19}F is an extremely sensitive nucleus and MRS can be used to study the pharmacokinetics and metabolism of fluorinated drugs, including volatile anaesthetics.

Sodium (^{23}Na)

Though the naturally occurring isotope of sodium is NMR visible, its sensitivity is greatly reduced by the fact that its nucleus is quadrupolar, a property that causes it to possess somewhat different spectral and relaxation properties than the other nuclei listed above. Sodium MR has been chiefly used in the imaging of experimental and clinical oedema.

Imaging applications [9]

Spatial localisation of NMR signal

Magnetic resonance imaging (MRI) utilises the proton signal from water to produce high resolution images of the body. The exciting B_1 field is confined to one or more slices by the use of transient magnetic fields (termed gradients). The signal from individual picture elements (or pixels) within this slice are 'encoded' for recognition by the use of gradient magnetic fields that are applied during data acquisition. This enables the data collection process to assign the signal from different parts of the body slice studied to appropriate parts of the pixel matrix on the screen or film (Fig. 15).

Production of image contrast

The intensity of signal in any given pixel depends on the density of water protons in the region, the delay between excitation and data collection, and the time allowed for recovery between successive excitations. If the delay between excitation and signal collection is long (a T_2 weighted image), the process will tend to produce contrast between areas where water protons have a short T_2 (relatively low signal) and areas where the water protons have a long T_2 (relatively high signal) (Fig. 16). Similarly, manipulation of the interval between successive repetitions can produce contrast between regions with different proton T_1 values (a T_1 weighted image). Other processes, too complicated to discuss here, also contribute to image contrast and their manipulation can reveal subtle differences between areas with different anatomy, physiology and pathology, to an extent not possible with other imaging techniques. An additional advantage of MRI is the fact that unlike X ray computed tomography, images can be obtained in any plane — transverse, sagittal, coronal or oblique (Fig. 17).

Three other aspects of MRI are worth mentioning. First, images can be sensitised to detect and quantify molecular diffusion and, in principle at least, tissue perfusion. Such imaging is still in its infancy but holds great promise for the future. Second, although conventional MRI does take minutes to acquire images, newer methods of fast imaging enable the production of tomographic snapshots with subsecond imaging times. This greatly improves the ability to perform dynamic scanning, and reduces respiratory, cardiac and peristaltic motion artifact. Finally, there are now increasing numbers of MR contrast agents which can improve the clinical utility of MRI. These alter image contrast by their ability to alter local magnetic field. For example, one such agent, gadopentate dimeglumine (Gd-DTPA, Magnevist), increases signal intensity on T_1 weighted scans. Since it does not cross the intact blood brain barrier, local increase in signal can demonstrate breakdown of the blood brain barrier, and fast imaging after intravenous administration can follow its passage

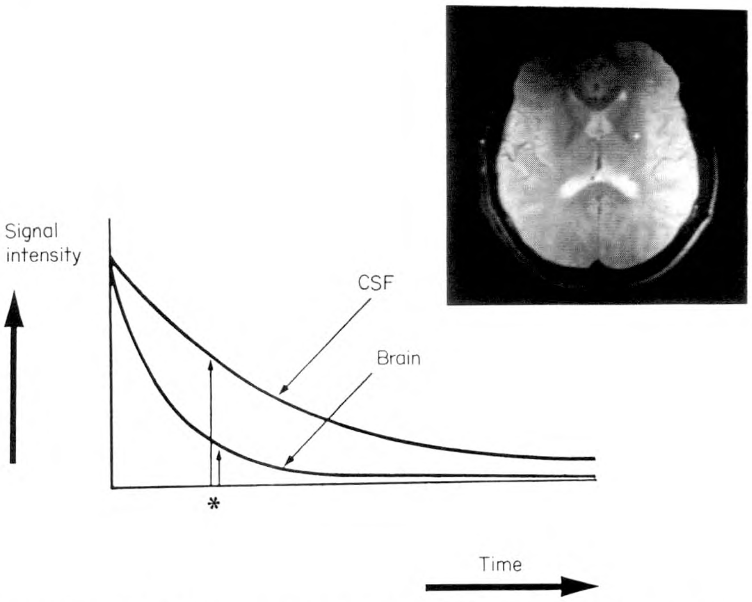

Fig. 16. Superimposed T_2 decay curves for signal from CSF and brain. The signal intensity from both structures is initially similar, but decays more rapidly with time in brain (where the T_2 is less). As a result, at the time of data collection (*) CSF exhibits a more intense signal than surrounding brain due to in the T_2 weighting in the image shown (SE 3000/80 at 1.6 tesla).

through the cerebral circulation and produce images that reflect cerebral perfusion.

Practical aspects

Field strengths in use for clinical MR

Magnetic field strengths in use for MRI and MRS are measured in units called tesla (T). One tesla equals 10 000 Gauss, and the earth's magnetic field at the surface is of the order of 0.5–1.0 Gauss. Field strengths in use for imaging range between 0.05 and 2.0 tesla, increasing strengths being associated with better spatial resolution, but also with greater expense and some technical problems. The higher field ($\geqslant$ 0.5 tesla) systems tend to be based on cryogenic magnets with superconducting coils operating in liquid helium (4.22°K), while the lower field systems may be based on resistive (room temperature) electromagnets or permanent magnets. *In vivo* spectroscopy generally requires field strengths of 1.5 tesla or higher, although proton spectra have been acquired at 1.0 tesla.

Hardware for MR studies

In practical terms, the whole body magnet consists of a long tube, usually about 2 m in length (Fig. 18). The items of hardware required for imaging and spectroscopy are contained within the magnet bore, leaving a free bore diameter for patient examination that ranges from 50–65 cm. The part of the body to be examined (e.g the head) may be enclosed within a smaller coil, which can

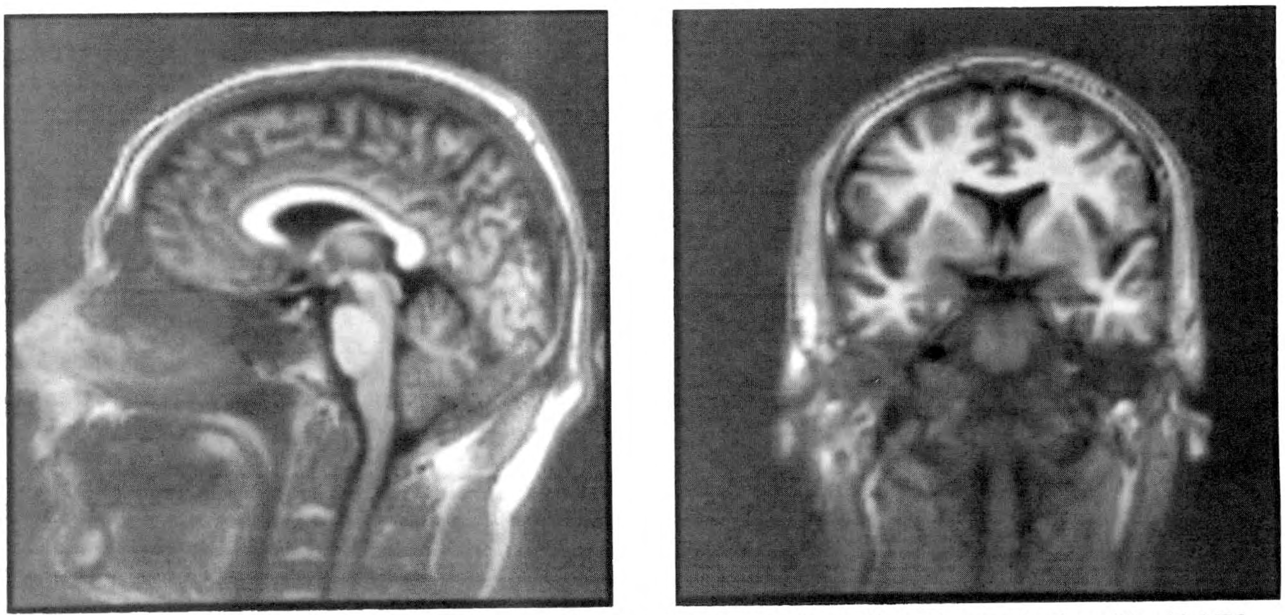

Fig. 17. Sagittal and coronal inversion recovery images of normal brain showing the excellent soft tissue detail possible with MRI.

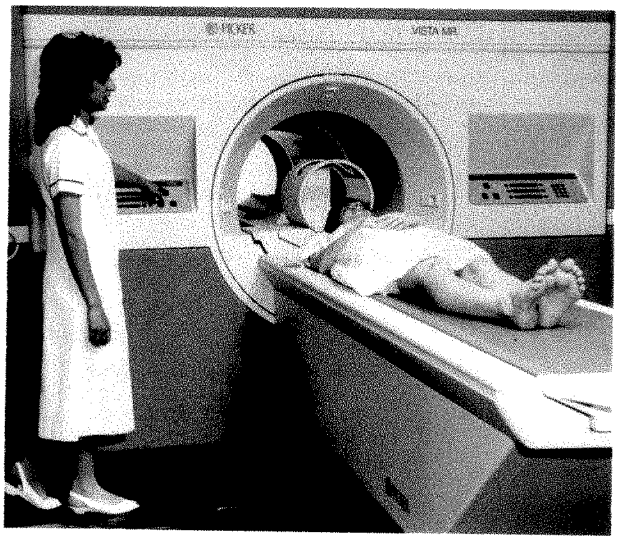

Fig. 18. A modern MR imaging system (courtesy Picker, UK). Note the relatively small dimensions of the magnet bore, and the imaging head coil which further restricts patient access.

substantially restrict access to patients. Access during scanning is further reduced by the fact that the portion to be examined is in the middle of the magnet (i.e. approximately 1 m from the end of the tube). The bore space of some of the lower strength noncryogenic magnets may be substantially larger, and some of the newer low field strength open magnet systems have greatly reduced problems of patient access.

The need for radiofrequency screens and filters

Since the NMR signals being studied are of very low intensity, they can be interfered with by stray high frequency electromagnetic radiation (such as radio waves transmitted by FM radio stations) or interference arising from electrical equipment or monitoring devices. It is common practice therefore, to enclose the scanning area in a radiofrequency (RF) shield or Faraday cage which may be either built into the fabric of the MR imaging room or immediately surround the magnet, in order to prevent the ingress of contaminating signals. Nonconductive devices such as ventilator tubing can safely be passed through the shield (using specially constructed copper lined RF ports), but wires that transgress the Faraday cage act as aerials and feed noise from the external environment into the examination area (Fig. 19). This problem is overcome by filtering wires that run in and out of the Faraday cage (Fig. 20) in one of several ways. Standard [10] or ECG gated [11] bandpass electronic filters are most commonly used, but the area within the cage can be isolated by using an optical [12] or radio link (employing frequencies that are far from the one being studied) [13]. An alternative method is to house the monitoring equipment within a small Faraday cage which is situated within the radiofrequency shield [14]. If standard radiofrequency Pi (π) filters are used, care must be taken to match filters to specific monitors. We have found that the readings from the Nellcor N-200 pulse oximeter, for example, are falsely high when the signal is passed through filters that seem acceptable for ECG and arterial waveform signals (Murata–Erie 9001–100–1021; STC Mercator, Great Yarmouth); accurate readings can however be obtained if somewhat less stringent filtering is used (Oxley FTLM/P/5000; Oxley

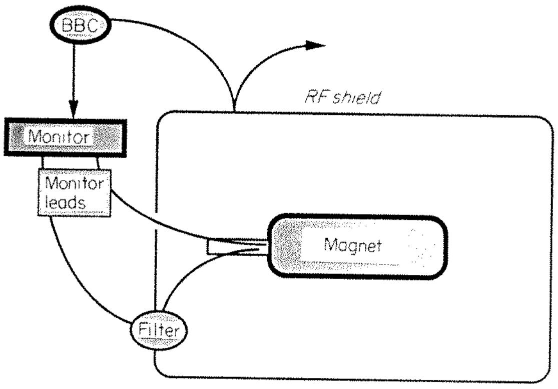

Fig. 19. Radiofrequency interference from external sources (labelled BBC) and monitoring equipment is prevented from entering the imaging area by the RF shield. This shield is breached by monitoring cables that can pick up and carry interference into the scanner. The interposition of low pass filters in the circuit prevents this.

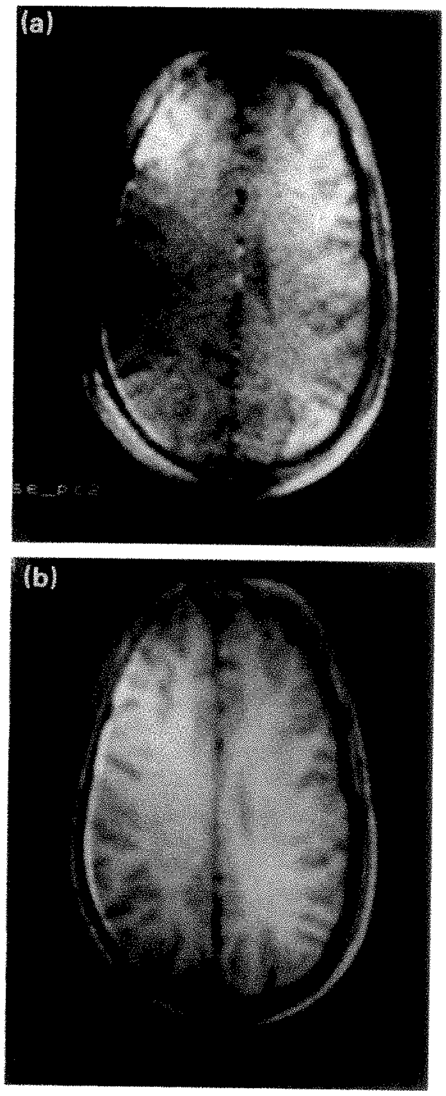

Fig. 20. Transverse T_1 weighted images of the brain of a normal volunteer demonstrating (a) the interference produced by an unfiltered pulse oximetry lead. In (b) the monitor lead has been filtered through a low pass RF filter, thus excluding the interference.

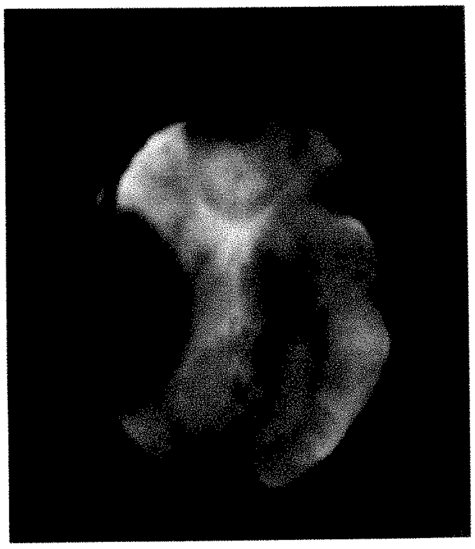

Fig. 21. Transverse images of a head with standard precordial stethoscope placed on the left infraclavicular region, demonstrating the imaging artifact produced by metal objects.

Developments, Ulverston, Cumbria). This may be due to the fact that the former filter distorts the leading edge of the signal from the pulse oximeter. It must be remembered that mains wiring can also carry interference into the Faraday cage. This obviously has implications for power supply to anaesthetic monitoring equipment within the Faraday cage; such devices will need to have an adequately filtered and isolated power source or be run by batteries. If the former option is chosen, it must be remembered that the small leakage currents present in π filters may activate isolation fault detector circuits in medical equipment, even though the device may continue to function normally [10]. If the latter option is chosen, it must be ensured that the batteries, which are usually strongly magnetic, are adequately secured to prevent them becoming dangerous projectiles (see below).

Safety considerations [15]

Ferromagnetic metal objects

The attractive force of the magnet exerts a substantial pull on ferromagnetic objects and, when free, these can move towards the magnet centre with dangerous speed. The attractive force on a ferromagnetic object can be several times that of the earth's gravitational field by the time it reaches the centre of a high field magnet, and there are anecdotal reports of impalement by runaway forklift trucks during construction near an MR imaging facility. In practical terms, however, scissors, paging devices and oxygen cylinders probably constitute a less dramatic but more frequent risk to patients.

These attractive forces also affect implanted prosthetic devices such as joints, cardiac valves or vascular clips. This problem is less prominent than it first appears because a large proportion of implantable metallic devices used in medical practice are nonferromagnetic [16]. The presence or absence of ferromagnetism in a given metal object depends on a number of factors, including its composition and manufacture [15]. Individual objects can be tested for ferromagnetism with a powerful hand held magnet or by suspending them by a string in the magnet bore, and observing whether the string is deflected from the vertical.

Objects that are ferromagnetic may still be safe because their mass is too small for the forces involved to be significant, and/or because they are firmly anchored in position. As an example, many prosthetic cardiac valves are attracted, to some extent, by magnetic fields, but the magnetic forces acting on most of these valves, even during high field imaging, are less than those produced by the beating heart [16]. Similarly, surgical clips that have been *in situ* for years are well anchored by surrounding scar tissue, and even newly inserted sternal sutures are sufficiently immobilised to be safe in the magnet. However, metallic objects in vulnerable positions such as cerebral aneurysm clips and intra-ocular foreign bodies must not be risked within the magnet field unless they are unequivocally known to be constructed of nonferromagnetic material, however long they have been in position. Patients may suffer major intracranial or vitreous haemorrhage if this guideline is ignored [17]. Plain X rays of the orbit probably constitute adequate screening for intra-ocular foreign bodies in high risk subjects [17, 18], though some centres use thin slice X ray CT [19]. Less than 5% of MR sites in the USA use metal detectors for screening patients, and it is generally agreed that such devices are insensitive and have little, if any, role to play in screening patients prior to MR examinations [11].

Nonferromagnetic metal objects

Even nonferromagnetic implants must be treated with care if they are in close proximity to the region to be scanned. This is for two reasons. First, metal objects (including anaesthetic apparatus [20] and tattoos [21] or cosmetics [22] that contain metal) can distort the field sufficiently to cause degradation of image quality (Fig. 21). Second, the application of intermittent radiofrequency B_1 fields to metallic objects can lead to heating and the danger of burns. Standard practice in such situations is for the patient to inform the operator if the area in question feels warm or uncomfortable, but this cannot apply to anaesthetised or unconscious patients. It is the anaesthetist's duty in such situations to obtain an assessment of risk from radiological or scientific staff in the MR unit. Electrical current induced in conductors may cause arcing, and currents in a pulse oximeter probe have been recorded as a cause of patient injury [23]. However, the risk of such burns is small and can be further reduced by simple safety precautions (see practice guidelines). In the current medicolegal climate it is important to record the fact that the above dangers have been guarded against, and that monitoring sites have been checked for injury at the end of the procedure (see below).

Fringe fields and medical equipment

The field strength of a magnet is quantified in the middle of the magnet where imaging and spectroscopy are undertaken. However, this field does extend beyond the margins of the magnet, decreasing in strength with distance from the magnet bore. This peripheral or fringe field can be responsible for malfunction of electrical or electronic equipment, erase magnetic tape (such as that on credit cards) or computer discs, or cause pacemakers to dysfunction. It is important therefore, that anaesthetists are aware of the extent of fringe fields of the MRI installations that

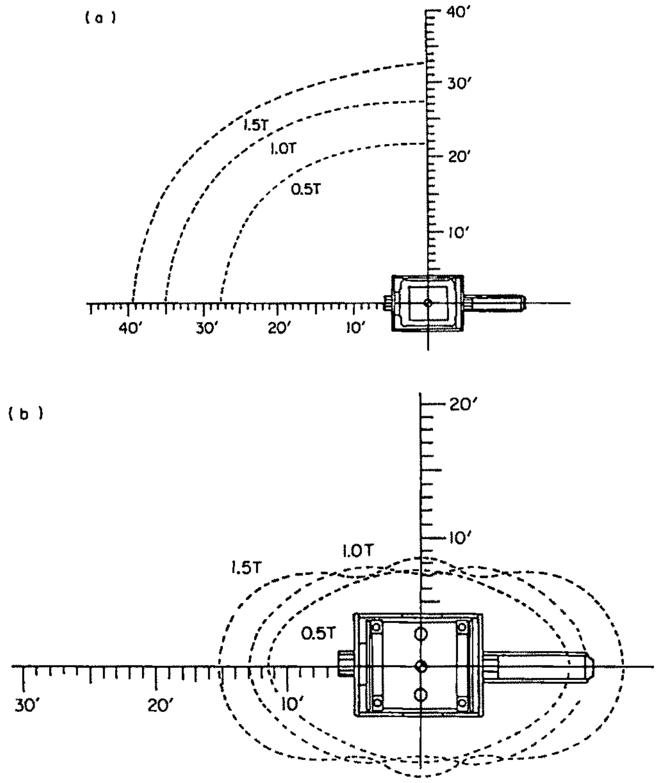

Fig. 22. Diagrammatic representation of 5 Gauss lines for (a) unshielded, and (b) actively shielded MR systems of different field strengths. Courtesy of Picker International Inc. Axes are calibrated in feet.

they work in. The most important determinant of the extent of such fields is magnet strength (Fig. 22(a)), but recent technical innovations have produced actively shielded magnets whose fringe fields are substantially reduced. In the case of standard high field cryogenic magnets the fringe field may extend for several metres away from the magnet, but may be much more compact in the case of low field resistive magnets or electromagnets. Developments in magnet technology have enabled the production of high field magnets with fringe fields that fall away very rapidly (Fig. 22(b)), thus enabling ferromagnetic equipment to be sited relatively close to the magnet. However, it must be remembered that such fringe fields also tend to rise rapidly as the magnet is approached, and great care must be taken to prevent ferromagnetic equipment from being inadvertently taken dangerously close to the magnet.

Practice guidelines

In practice, the anaesthetist needs to ascertain where the 5 Gauss and 50 Gauss lines on the fringe field are. The reed switch on demand pacemakers malfunctions at field strengths above 5 Gauss [24] and patients with pacemakers should not be subjected to MR examination or allowed to cross a 5 Gauss line. Pacemaker malfunction in magnetic fields has been documented in animal models [25], and has been cited as causing death from arrhythmia in patients [26]. The situation with other implantable battery driven devices is less well recognised. Some cochlear implants may actually use cobalt samarium magnets to retain external coils [27]; most of these devices are electronically controlled. Similarly, implantable infusion pumps, neurostimulators and automatic implantable cardiac defibrillators have electronic control circuitry which may dysfunction in magnetic fields, and the motors of infusion pumps may not operate accurately at fields in excess of 100 Gauss. It seems prudent therefore, to suggest that patients with such devices *in situ* should not undergo MR examinations [15]. Concerns have been expressed that epicardial pacemaker wires and intracardiac catheters may act as aerials and deliver high frequency currents to the myocardium. Although there is no evidence to support such fears, some authors have suggested that patients with such devices should not be exposed to MR examination [15]. The uneventful examination at the Hammersmith of over 20 patients with epicardial pacing wires *in situ* within 24 h of open cardiac surgery suggests that the risks are not great, at least at low field strengths (0.15 tesla). It is essential, however, that the ends of the two pacing wires are well separated by insulating material, thus preventing the formation of a conducting loop.

The attractive force on ferromagnetic objects tends to become significant at field strengths of about 50 Gauss, and it is generally agreed that objects such as ferromagnetic gas cylinders are stationed outside the 50 Gauss line.

This risk of burns from monitoring cables can be minimised by following some simple precautions: (1) check that the insulation on all monitoring wires and MR cables is intact; (2) do not form loops within the magnet bore, and minimise contact between cables; (3) remove any wires or leads not in use; (4) separate cables from skin (by padding if necessary); (5) keep the cable and sensor away from the examination area e.g. place a pulse oximeter on the toe of a patient whose head is being examined.

Effects on monitoring devices

Other electronic and electrical equipment may also be affected. Colour cathode ray screens are distorted by fields that exceed 1–2 Gauss, while monochrome screens may function reasonably well up to 5 Gauss. Magnetic tape and computer disks are corrupted by fields of 30 Gauss or higher. Most monitoring and infusion devices function normally at fields of 50 Gauss or less (field strength inferred from Karlik *et al.* [10]).

We have noted that many devices operated by rechargeable batteries tend to switch off and blank their screen when magnetic gradients operate. This effect, in fact, limits how close we can get to our MR system with pulse oximeters and monitoring display screens. We are as yet, unsure of the reason for this, but such malfunction may be due to the effects of the rapidly changing magnetic fields on either microprocessor circuitry or current inverters within the instrument.

Auditory considerations

Operation of gradient coils often produces a loud thumping or tapping noise. The levels of noise permitted by regulatory bodies is clearly defined, and most commerical MR systems do not exceed these [15]. However, there have been reports of temporary and permanent hearing loss following MR examinations [15]. Furthermore, even levels of noise that do not produce hearing loss may necessitate deeper levels of anaesthesia than otherwise needed for MR examinations. Magnet compatible earplugs are commercially available and can provide a simple solution to this problem [15]. An ingenious new method to reduce noise levels during MR imaging involves the feeding of noise in antiphase to produce noise cancellation [15].

Contrast agents in MRI [15]

The pharmacology and toxicology of such agents is substantially different from conventional radiographic contrast media. The most common of the MRI contrast agents, gadopentate dimeglumine (Gd-DTPA, Magnevist) has a high therapeutic ratio and a low incidence of side effects (2.4%) when compared with iodinated contrast agents. Side effects that have been reported include headache, nausea, vomiting, burning at the site of injection (the preparation is hyperosmolar) and hives. There have also been reports of transient severe hypertension and anaphylactoid reactions (with an incidence of about 1:100 000). Although there have been isolated reports of fatalities temporally related to administration of the drug, no causal effect has been demonstrated. Other MR contrast agents are being introduced into practice, and anaesthetists may need to acquire familiarity with these drugs.

Cryogens and quenches

All superconducting systems are based on cryogenic magnets operating in an environment of liquid helium at 4.22°K, while many older magnets also have a cryostat buffer consisting of liquid nitrogen at 77.3°K. These gases are normally maintained in their liquid state by insulation and losses due to evaporation are usually small. If the temperature of the cryostat rises suddenly for any reason however, these gases may 'boil off' rapidly in an explosive event known as a quench. Helium vapour (which resembles steam) is lighter than air and will rise, whereas gaseous nitrogen is approximately the same density as air. The distribution of the gases during a quench will reflect their physical properties, and have two potential hazardous effects. First, dilution of available oxygen by inert gas can result in asphyxiation. Second, the condensing vapour can result in frostbite and/or cryogenic burns. Most superconducting MR systems should have efficient ventilation systems to cope with such an eventuality, and witnessed quenches have usually been relatively gradual events. However the onset of asphyxia may be extremely rapid, with little or no warning [15], and more gradual reductions in ambient oxygen levels due to slow leaks may be difficult to detect. It has been suggested that oxygen monitors (e.g. the Sabre CM 610; Sabre Gas Detection, Aldershot, Hants GU12 4DL) be sited within areas at risk of quenches, and set to sound an alarm when levels drop below 19–20% [15].

Biological effects [15]

Effects of static magnetic fields

Fears of biohazard associated with exposure to magnetic fields have prompted a number of studies in unicellular organisms, cell systems, animals and humans. Isolated studies have demonstrated effects of magnetic fields on embryogenesis, insulin release, blood–brain barrier permeability, haemostasis, plasma enzyme levels, and other biological functions. Other experiments and the vast majority of human data to date however, suggest that static magnetic fields do not have any significant deleterious effects on patients or health care professionals exposed to MR procedures.

Blood is a conductive medium, and when it flows in a magnetic field, tends to induce a voltage across the vessel. This voltage is maximal when flow is at right angles to the lines of magnetic flux, and is hence most prominently seen in the arch of the aorta in patients who are in the magnet. Such potential differences can distort the electrocardiogram and theoretical extrapolation of results from animal experiments suggest that the voltages induced in myocardiac vessels may reach depolarisation thresholds above 2.5 tesla [28]. Clinical experience and further animal work (at up to 4.7 tesla [29]) have failed to confirm these fears.

Effects of rapidly switched gradient fields

Gradient fields switch at rates of around 1–5 tesla.s^{-1} [15] (up to 100 tesla.s^{-1} with newer fast imaging sequences) and may induce currents in biological tissue. These currents do not generate enough heat to cause concern about thermal effects, but they may have electrophysiological consequences. Recent studies have reported peripheral muscle stimulation by gradient fields in volunteers at thresholds of 60 tesla.s^{-1} and the stimulation of retinal receptors with the production of visual sensations (termed magnetophosphenes) have been reported at field strengths above or around 2 tesla. Theoretical and experimental evidence indicates that gradient switch rates of 1 tesla.s^{-1} result in tissue current densities of around 1 $\mu\text{A.cm}^{-2}$. Extrapolation of these results would suggest that switch rates in excess of 300 tesla.s^{-1} would be required to induce ventricular fibrillation [30]. Many reports suggest that noncardiac excitable tissue is excited at a lower threshold value, thus providing a relatively sensitive marker of dangerously high gradient switch rates [30]. There are some 4 tesla MR systems in use now, and there are documented instances of metallic taste, nausea or vertigo being produced when subjects are pushed rapidly into these magnets [15].

Effects of radiofrequency time varying magnetic fields (B_1 fields)

These are magnetic fields that oscillate at the resonant frequency, and can produce electrical currents in tissue. In contrast to the currents produced by gradient fields, the currents produced by radiofrequency time varying fields have no significant electrophysiological effects, but can cause significant heating. The occurrence of heating in metallic implants has been discussed, but thermal effects may also be seen in biological tissue. Rises in temperature depend not only on thermal energy deposition, but also on the rate at which heat is lost. There are clear guidelines for permissible levels of heat deposition prescribed by the National Radiological Protection Board in the UK and by the FDA in the USA [31, 32]. Similar recommendations exist for Canadian MR sites [33]. Special concerns have been expressed regarding the effects of scrotal heating on spermatogenesis, and the possible generation of cataracts by ocular heating; studies to date suggest that such fears are unjustified in the context of radiofrequency fields used for clinical examination [15].

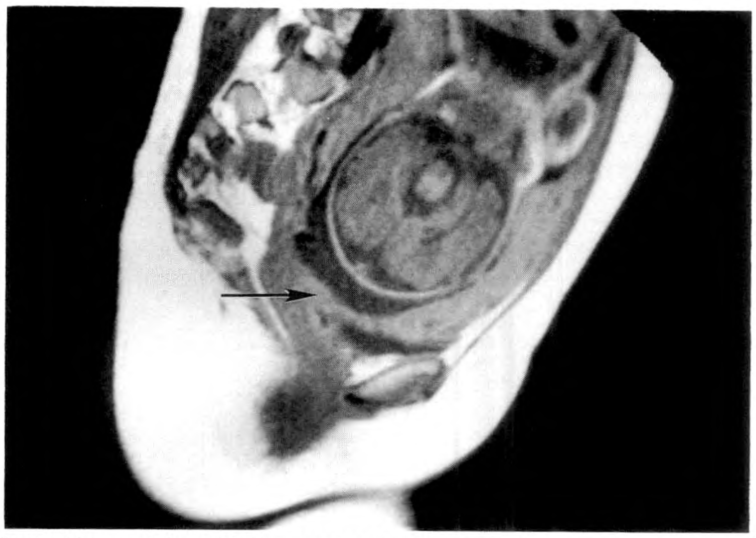

Fig. 23. Sagittal image of the pelvis in a pregnant female at term demonstrating a placenta praevia (→). Image courtesy of Miss H.A. Case, Bristol MRI Centre.

Carcinogenic and teratogenic risks

The potential of radiofrequency magnetic fields in producing cancer or developmental abnormalities is an area of critical debate. The interested reader is referred to reviews by Adey [34] and Beers [35]. There appears to be no evidence to suggest that exposure to the fields used in MR imaging and spectroscopy is associated with any significant increase in the risk of developing cancer. Similarly, there is little hard evidence to support the suggestion that routine clinical exposure to MR examinations may cause developmental abnormality, and authorities in the field suggest that MR is the imaging procedure of choice at any stage of pregnancy if ultrasound is inappropriate or provides inadequate information [15] (Fig. 23). Occupational exposure to MR procedures (radiologists, radiographers, nurses) is however, minimised by many MR units [11], and it has been suggested that pregnant personnel are not exposed to time varying magnetic fields or to static fields in excess of 10 Gauss [15].

Recording information during MR studies

The long list of contraindications and hazards listed above makes it important that patient assessment and procedure planning prior to MR examinations be formalised in some way. Many MR units use a checklist, which is often given to patients to fill in while they await their MR study. If patients are unconscious, such information may need to be acquired from several sources, and filled in by medical or paramedical staff. In any case, before an anaesthetist accepts responsibility for caring for a patient in an MR scanner he or she must ensure that a suitable checklist has been filled in (Table 2), since we have found that verbal assurances of safety from referring clinicians can be misleading. For anaesthetised or sedated patients, an additional 'anaesthetist's MR checklist' may be valuable (Table 3). The combination of these two checklists provides the basis of safe anaesthetic practice in an MR environment for the individual anaesthetist, who may be infrequently involved in MR studies. Anaesthetists may come into contact with MR in two other situations. First, there is the anaesthetist who is responsible for setting up equipment for monitoring and anaesthesia in an MR unit; issues which are dealt with in Part II of this paper, along with details of anaesthetic practice. Second, there is the anaesthetist who may use MR as a research tool as exemplified by the studies listed in the next section.

Some clinical MR studies of special anaesthetic interest

The last decade has seen an explosion of research employing MRI and MRS. We would like here to touch upon some of the clinical studies which may be of special interest to anaesthetists and intensivists.

Phosphorus spectroscopy of the brain in birth-asphyxiated neonates

The physiological changes associated with neonatal hypoxic–ischaemic injury result in changes in energy metabolism within the brain that have been studied using ^{31}P MRS [36–38]. In the hyperacute stage there is an intracellular acidosis but no other change in the phosphorus spectrum. Over the first 48 h cerebral PCr levels drop while Pi levels rise, suggesting a worsening energy state within the cell (Fig. 24). These changes revert to normal over 10–14 days. The initially acid pH normalises at first, but then exhibits an alkaline overshoot. The clinical relevance of these changes lies in their proven ability to provide a noninvasive index of outcome [37], and they show great potential in the assessment of neuroprotective agents. We have, more recently, used ^{1}H MRS to study neonatal injury at longer intervals after birth asphyxia [38].

Phosphorus spectroscopy in the diagnosis of malignant hyperpyrexia

Studies of muscle from patients with malignant hyperthermia (MH) have shown that the abnormal muscle metabolism in this condition can be diagnosed with a high degree of accuracy using ^{31}P MR spectroscopy [39] (98%

Table 2. Checklist for patients undergong magnetic resonance imaging/spectroscopy.

It is the responsibility of the NMR Unit staff member who puts the patient in the magnet to satisfy himself or herself that the following checklist is completed. This may involve obtaining information from the patient or patient notes, from the referring doctor, or in some cases, obtaining previous or fresh radiographs to exclude metallic objects.

Device category	Yes	No	Unsure
1 Heart pacemaker (any type).	____	____	____
2 Cerebral aneurysm or other haemostatic clips.*	____	____	____
3 Metal fragments in head/eyes — postoperative/post-trauma.	____	____	____
4 Shrapnel.	____	____	____
5 Prosthetic heart valves (Starr Edwards pre 6000).*	____	____	____
6 Orthopaedic implants (pins, plates, wires).*	____	____	____
7 Cochlear implants.*	____	____	____
8 Neurostimulators (Chronic pain therapy or spasticity).*	____	____	____
9 Implantable pumps.*	____	____	____
10 Penile implants (Omniphase, Decomed Corp).*	____	____	____
11 Contraceptive diaphragms/IUCDs.*	____	____	____
12 Coloured contact lenses.*	____	____	____
13 Ocular prostheses (false eyes).*	____	____	____
14 Interventional radiology devices (coils, filters, stents).*	____	____	____
15 Dentures or removable bridgework.	____	____	____
Other information			
16 Has the patient ever been a machinist or metal worker?	____	____	____
17 Is there any possibility that the patient may be pregnant?	____	____	____

*Note: Some devices in this category may be safe while others are not. Listings are incomplete. A device not known to be safe must be assumed to be unsafe. In the case of devices operated by microprocessors (e.g. implantable pumps) device malfunction caused by field effects on circuitry must be considered. Other devices such as ventricular shunts, orthodontic braces may be safe, but may degrade image quality significantly. Images may also be degraded by metal containing tattoos or cosmetics. (See *Radiology* 1991; **180:** 541.

This is to confirm that the above checklist has been completed.

Signed:__________(Patient)__________(NMR Unit Personnel)

Dated: ____/____/____

Table 3. Anaesthetic checklist for MR procedures.

Remove metallic objects (including paging devices), nondigital watches and credit cards, check your pockets for dangerous metallic objects (scissors, artery forceps, pens, needles, paper clips etc). Do not take credit cards, computer floppy discs, or other magnetic data storage devices near the magnet.

1 Ensure that (a) anaesthetic/monitoring equipment is working [ ]
  (b) there is a suitable area for induction/recovery [ ]
  (c) the breathing system in the magnet area is long enough to allow transfer from the oxygen cylinder outside the 50 Gauss line. [ ]
2 Consent form signed. [ ]
3 Day case criteria satisfied if needed. [ ]
4 MR safety checklist completed; contraindications excluded. [ ]
5 Magnetic and metallic objects removed from patient, including eye makeup and prosthetic devices if appropriate. [ ]
6 Placement of MR compatible monitoring leads. If patient already has monitoring on, these leads may need to be removed. [ ]
7 Interposition of appropriate lengths of extension line to i.v. access site (and infusion pumps, if appropriate). [ ]
8 Induction of anaesthesia on an MR compatible trolley. [ ]
9 Move patient to magnet area and position for examination. CHECK THAT FERROUS OXYGEN CYLINDER IS REMOVED AND INFUSION PUMPS ARE AT A SAFE DISTANCE FROM THE MAGNET. [ ]
10 Connect monitoring devices and anaesthetic breathing system and check function. [ ]
11 Ensure that i.v. access will still be available when the patient goes into the magnet bore. [ ]
12 Patient moved into magnet bore. Monitoring and receiver coil leads are separate, and there are no non-essential cables or potentially dangerous inductive loops. [ ]
13 MR procedure complete. Remove patient to induction/recovery area, with transfer to cylinder gases outside 50 Gauss line. [ ]
14 Reversal of anaesthesia and recovery. Check monitoring sites for burns and record their presence or absence in the notes. [ ]

sensitivity, 96% specificity *vs* muscle biopsy contracture tests with halothane and caffeine). ^{31}P MR spectra from patients with MH show a higher Pi/PCr ratio than controls and exhibit a slower recovery in PCr levels after exercise. These studies provide not only a noninvasive means of diagnosing MH, but also an opportunity to study the pathophysiology and biochemistry of the disease [40].

Fluorine spectroscopy of volatile anaesthetics

Many authors have published ^{19}F MRS studies of halothane, enflurane and isoflurane in animals. These studies have mapped the distribution of halothane in the head [41], identified two discrete physicochemical environments for halothane binding [42, 43], and studied the uptake and elimination of volatile anaesthetics from the brain [44, 45]. Recent work at this centre has duplicated many of these studies in humans [46]. ^{19}F MRS may provide us with a powerful tool to study the pharmacokinetics and metabolism of fluorinated volatile anaesthetics.

MR imaging of patients after anaesthesia

Many authors have used *in vitro* proton spectroscopy to study the effects of general anaesthetic agents on the mobility of macromolecules [47] and model lipid bilayers [48]. Whitfield and Douglas used T_2 weighted MR imaging to assess tissue molecular mobility in the brain after general anaesthesia [49]. One to 3 h after general anaesthesia, patients showed small increases in cerebral T_2 values as measured by imaging on a 0.2 tesla MR system. These changes show how MR imaging may be used to study, and perhaps validate theories of general anaesthesia *in vivo*.

Conclusion

Clinical magnetic resonance imaging has been in use for over a decade, and its availability and use is increasing. Our experience suggests that ideally no anaesthetised or

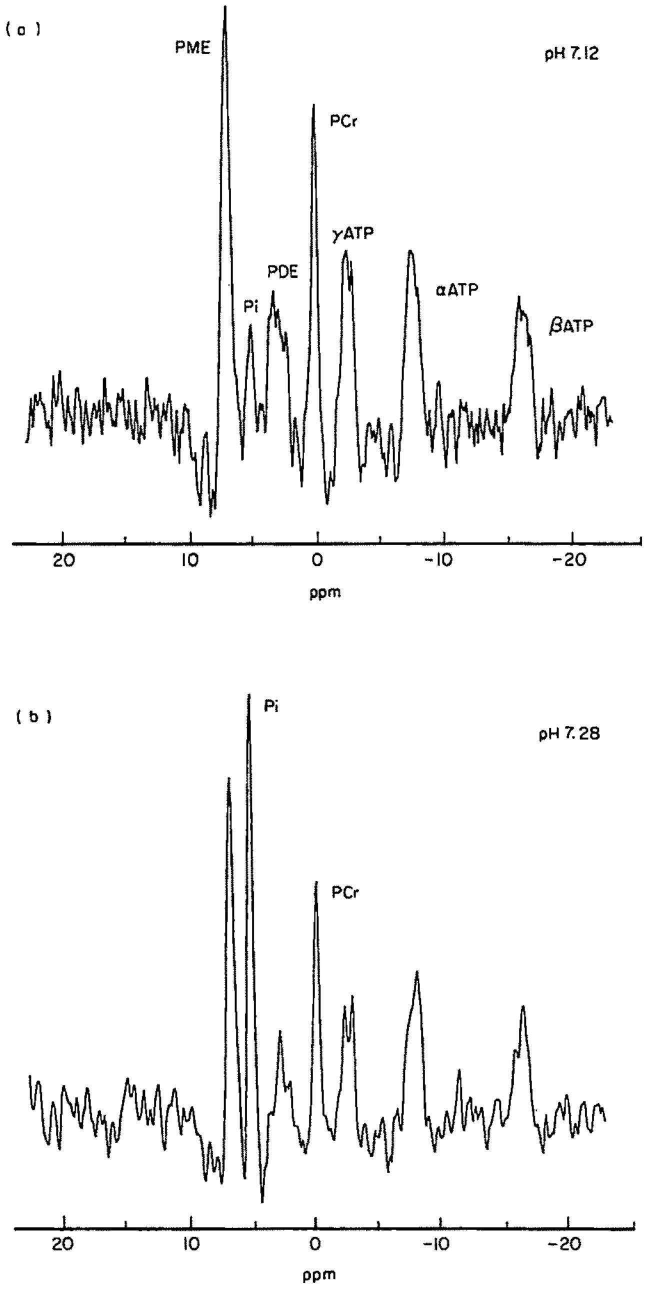

Fig. 24. ^{31}P MR spectra of the brain from (a) a normal neonate, and (b) a baby with birth asphyxia, at 4 days postnatal age. Note the reduction in PCr/Pi ratio and the relatively alkaline pHi in (b), both of which are characteristic of the subacute phase of hypoxic-ischaemic neonatal CNS birth injury.

critically ill patient should be subjected to MR procedures without adequate monitoring and continuous supervision by an anaesthetist who is fully conversant with the potential problems and risks of the procedure. An understanding of the basic principles involved will facilitate the acquisition of the knowledge needed for this process, and provide an opportunity to consider the application of this exciting technique to answer questions that interest anaesthetists.

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Forum

Oxyhaemoglobin saturation following elective abdominal surgery in patients receiving continuous intravenous infusion or intramuscular morphine analgesia

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Summary

Oxygen saturation was continuously measured using computerised pulse oximetry for 8 h overnight pre-operatively and for the first 24 h postoperatively in 40 patients receiving intermittent intramuscular morphine or continuous infusion of morphine following elective upper abdominal surgery. The proportion of time with an oxygen saturation less than 94% was used as an index of desaturation. Patients receiving continuous infusion analgesia received a larger morphine dose and achieved better analgesia than the intramuscular group. Postoperatively, the duration of desaturation increased 10-fold over pre-operative values, 'intramuscular' patients spending 39.0% (SD, 37.0%) and 'continuous infusion' patients 40.0% (SD, 37.5%) of the time below 94% saturation. Although newer therapies (e.g. epidural analgesia and patient-controlled analgesia) are currently receiving greater attention, the sequelae of these more traditional analgesic techniques warrant further study.

Key words

Monitoring; oximetry.
Complications; hypoxia.
Analgesics; morphine.
Pain; postoperative.

During the past 30 years the occurrence of intermittent and sustained postoperative hypoxia has been reported [1–3]. The introduction of newer methods of opioid delivery e.g. patient-controlled analgesia (PCA) [4] and spinal opioids [5] has promoted considerable research into adverse effects of these techniques, particularly respiratory depression. In contrast, there has been little work looking at what actually happens following traditional methods of opioid delivery such as intramuscular injection (IM) and continuous intravenous infusion (CI). Catling *et al.*, using the indices of respiratory rate, tidal volume, number of apnoeic episodes and partial pressure of carbon dioxide showed there were differences between IM and CI analgesia following cholecystectomy [2]. However, these measurements were intermittent, and pulse oximetry was not used. Continuous pulse oximetry, which has allowed accurate monitoring of pre-operative hypoxaemia, combined with computerised data collection, has enabled comprehensive analysis of patients' peri-operative oxygen saturation ($S\text{po}_2$). Brose *et al.* [6] comparing IM pethidine, PCA pethidine and extradural morphine for post-Caesarean section analgesia, reported that patients receiving PCA had long periods of mild desaturation (90–95%); in contrast, more severe desaturation (mean values 83%) occurred for shorter periods of time with extradural morphine and intramuscular pethidine. Continuous pulse oximetry was used by Wheatley *et al.* who studied patients undergoing lower abdominal procedures in order to assess the respiratory effects of extradural, PCA and IM analgesia [7]. These workers defined the pattern of $S\text{po}_2$ readings as stable or unstable depending on the hourly variability of oxyhaemoglobin saturations, and hypoxaemia as an $S\text{po}_2 < 94\%$ for more than 10% of the time. Patients receiving IM and PCA had unstable patterns of $S\text{po}_2$ values with no hypoxaemia, while 50% of patients receiving extradural morphine had unstable patterns of $S\text{po}_2$ values with prolonged periods of desaturation. Different methods of administering analgesic agents may give rise to different degrees of hypoxaemia; which method is associated with the least disturbance is unknown [8]. Continuous pulse oximetry has not been used to evaluate oxyhaemoglobin saturation during CI analgesia; moreover there has been no comparison of $S\text{po}_2$ with IM and CI analgesia following upper abdominal surgery.

The aim of this survey was to identify the incidence of postoperative hypoxia following upper abdominal surgery in our institution using computerised pulse oximetry. We also sought to identify any differences in $S\text{po}_2$ values between patients receiving IM and CI analgesia as routinely prescribed in our hospital.

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Table 1. Demographic data. Numbers expressed as mean (SD).

	IM (n = 18)	CI (n = 22)
Age; years	45 (15)	45 (14)
Duration of operation; min	96 (45)	100 (46)
Number of smokers	6	5
Intra-operative morphine; mg	10 (7.5)	8.5 (8.3)
Intra-operative fentanyl; μg	100 (90.7)	131 (213)

Method

Following institutional approval and written informed consent, patients aged between 18 and 70 years of age, of ASA physical status 1 or 2 who were undergoing elective upper abdominal surgery were recruited to the study. Patients with respiratory disease or documented sleep apnoea were not studied. Postoperative Spo_2 data were only collected on those patients for whom supplemental oxygen was not deemed necessary. If the anaesthetist or surgeon prescribed oxygen, the patient was withdrawn from the study. Premedication consisted of orally administered diazepam 10–15 mg, given 1–2 h pre-operatively. Other sedative drugs and peripherally acting analgesics were not prescribed during the course of the study. The anaesthetic technique in all cases consisted of thiopentone, atracurium or vecuronium, oxygen and nitrous oxide supplemented with enflurane. As this was a survey of current practice, intra-operative analgesia was not standardised, however the total dose of fentanyl and/or morphine administered was recorded. Furthermore, allocation of patients to receive either intermittent intramuscular morphine (IM) or continuous infusion of morphine (CI) for their postoperative analgesia was at the discretion of an independent anaesthetist at the time of surgery. In the recovery room, all patients received 1 mg increments of morphine intravenously to achieve maximal patient comfort. Subsequently, patients receiving IM analgesia were prescribed 10 mg intramuscular injections of morphine to be given 3 hourly as needed. Continuous infusion patients received a constant infusion of morphine at an initial setting of 2 $mg.h^{-1}$ and for inadequate analgesia, supplemental 1 mg bolus doses of morphine were prescribed. Postoperative monitoring consisted of hourly assessment of the sedation level (A = normal sleep, 0 = alert, awake, 1 = frequently drowsy, easily roused, 2 = very drowsy, easy to rouse and 3 = somnolent, difficult to rouse), unstimulated respiratory rate, and visual analogue pain scale (0–100). Hourly and total dose of morphine were recorded for both groups of patients.

Oximetry. Oxyhaemoglobin saturation (Spo_2) was measured overnight for a minimum of 8 h pre-operatively and for the first 24 h postoperatively following return to the ward. A Nellcor Oxisensor probe was attached to one of the patient's great toes and connected to a Nellcor N-200E oximeter. Measurement of arterial Spo_2 (integers in the range 0–100%) and heart rate (HR) were transmitted via the RS-232-C port of the pulse oximeter to a Toshiba T-1000 lap top computer. A program compiled from Turbo Pascal was created to allow the continuous logging of Spo_2, HR and time every 10 s with appropriate error trapping. Data were transmitted to the computer screen and then to disk file for subsequent analysis [9]. Monitoring was carried out continuously, except for a few brief periods when patients were out of their beds, at which time the sensor lead was disconnected from the cable by the patient or the nurse. Pulse oximetry is not routinely available on general surgical wards in our institution, therefore, so as not to change normal practice, the oximeter alarms were inactivated and the oximeter was concealed in a locked drawer where it was not visible to attending medical or nursing staff. Identification of hypoxaemic episodes was made at the conclusion of the study. At such time, the data stored on the disk were imported to a spreadsheet using a high-speed IBM-compatible PC (SuperCalc 4, Computer Associates) for initial data examination and graphing. Data were transmitted to an Encore mainframe computer for statistical analysis using SPSS-X (Statistical Package for the Social Sciences). Data analyses involved determination of the percentage of desaturation readings for each patient which were below 94% and below 85% pre- and postoperatively (PREDESAT and POSTDESAT). The Mann–Whitney *U* test was used to compare data between groups while multiple regression analysis was performed to investigate associations between Spo_2, morphine dose rate, mode of administration, and patient characteristics. Significance was taken at the 5% level ($p < 0.05$).

Results

Forty-nine patients were recruited for the survey, of whom 40 were suitable for subsequent analysis (IM, n = 18; CI, n = 22). Reasons for exclusion of patients included: incomplete data collection or failure of the pulse oximeter to transmit data to the computer (7) and breach of protocol (2). Groups were similar with respect to age, smoking status, total dose of intra-operative opioid and operative procedure time (Table 1).

The mean dose rate in the CI group (2.78 $mg.h^{-1}$) was almost twice that in the IM group (1.40 $mg.h^{-1}$, $p < 0.01$); this was associated with significantly lower pain scores ($p < 0.05$) in the CI group compared to the IM (Fig. 1). Despite the greater administered dose of morphine in patients receiving CI analgesia, sedation scores were not significantly different between groups ($p = 0.2$).

The duration of time spent at less than 94% saturation pre- and postoperatively was not different between the groups of patients who received either IM or CI analgesia. The proportion of time spent at levels of desaturation below 94% in the postoperative period was approximately 10-fold greater than pre-operatively (PREDESAT, IM

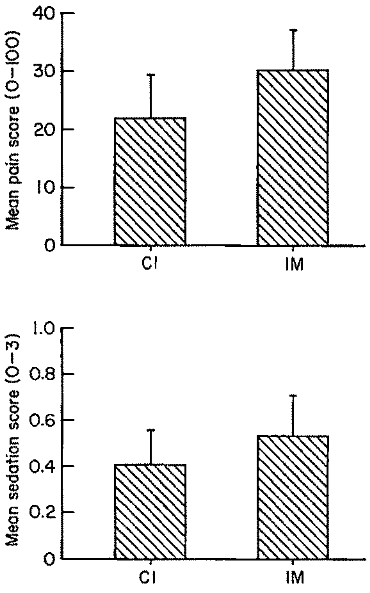

Fig. 1. Pain scores obtained from visual analogue scale (0–100) (above) and sedation scores (below) for the intramuscular (IM) and continuous infusion groups (CI). Results are expressed as mean (95% confidence interval).

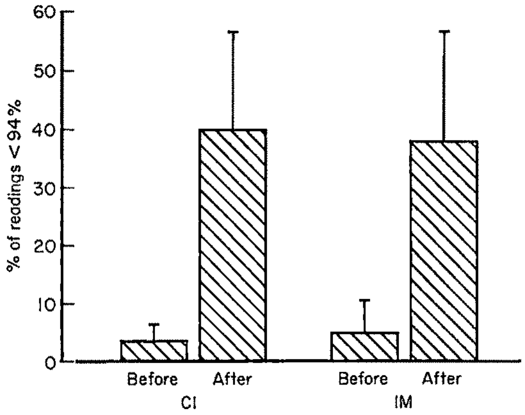

Fig. 2. Time spent below 94% saturation in the pre-operative and postoperative period for both IM and CI groups. Results expressed as mean (95% confidence interval). Significant difference between 'before' and 'after' levels ($p < 0.05$).

4.8%, CI 3.5%; POSTDESAT, IM 39%, CI 40%) (Figs 2 and 3) while severe desaturation (< 85%) occurred postoperatively for 2.2% and 4.0% of the time in the IM and CI groups respectively.

There was no relationship between mean or minimum respiratory rate and pain score, sedation score, rate of morphine administration or route of administration. Moreover, there was no correlation between the mean levels of saturation and mean respiratory rate (Fig. 4), or mean sedation level.

Multiple regression analysis was used to investigate factors which were possibly associated with POSTDESAT. The model providing the highest adjusted R^2 was:

$$\text{POSTDESAT} = \text{PREDESAT} + (20 \times \text{DR}) + (\text{AGE} - 33) - (28 \times \text{GROUP})$$
$$(\text{Adjusted } R^2 = 0.32,\ p < 0.05)$$

POSTDESAT = percentage time spent at $Spo_2 < 94\%$ postoperatively; PREDESAT = percentage time spent at $Spo_2 < 94\%$ pre-operatively; DR = dose rate of morphine ($mg.h^{-1}$); GROUP = 1 for patients in the CI group; GROUP = 0 for patients in the IM group.

Finally, Spo_2 values were plotted against real time to ascertain whether there was a temporal association between these events. It was noted that during the early morning hours, hypoxaemic events were more frequent and more pronounced. However, there was no correlation between sedation scores and Spo_2 values. The 24 h saturation profile of one patient receiving IM analgesia is shown in Figure 5. Spo_2 values were low in the early hours of the morning and, possibly associated with ward activity, increased later that morning.

Discussion

This survey of hypoxaemia following elective upper abdominal surgery has shown that healthy patients, with no history of lung pathology or sleep apnoea, receiving conventional analgesia spend a considerable time at oxyhaemoglobin levels of less than 94%. Wheatley *et al.* defined their hypoxaemic threshold at 94% and characterised hypoxaemia as an Spo_2 < 94% for greater than 6 $min.h^{-1}$ [7]. What constitutes a significant duration of desaturation is not known, so that while some investigators have specified time limits associated with periods of desaturation, we have included all such episodes within the 10 s sampling schedule. Moreover, although we chose values of < 94% and < 85% for data interpretation, other groups have used other thresholds e.g. < 90% and < 80%. We have provided information regarding all thresholds by using the cumulative time-saturation curves (Fig. 3). Rosenberg *et al.* [10] reported an increase in both constant (overnight mean values < 90%) and episodic (a reduction of > 5% from pre-operative levels or < 80%) hypoxaemia following routine elective general surgery, with an inverse relationship noted between heart rate and mean saturation. Using Holter monitoring, no association was found between episodes of desaturation and ECG abnormalities e.g. ischaemia or arrhythmias. Muir *et al.* [11] studied the postoperative oxygen desaturations and myocardial ischaemia of patients undergoing vascular surgical operations. Ischaemic episodes were more common in the postoperative period; silent ischaemia was more common on the third day postoperatively, and was associated with an Spo_2 < 85%. Sleep apnoea patients have been studied to identify the haemodynamic responses to oxygen desaturation. In one study elevation in the systolic blood pressure was related to the degree of desaturation, while transiently high levels of myocardial blood flow were needed to maintain oxygen balance during periods of sleep apnoea [12]. Animal experiments involving brief (15 min) episodes of ischaemia have shown that whilst individual episodes of ischaemia may not cause myocardial damage, repeated events have a cumulative effect and may predispose the animal to significant myocardial necrosis [13]. In normal patients the clinical significance of these periods of desaturation and ischaemia is unknown but cardiovascular (*vide supra*) and neurological sequelae have been suggested.

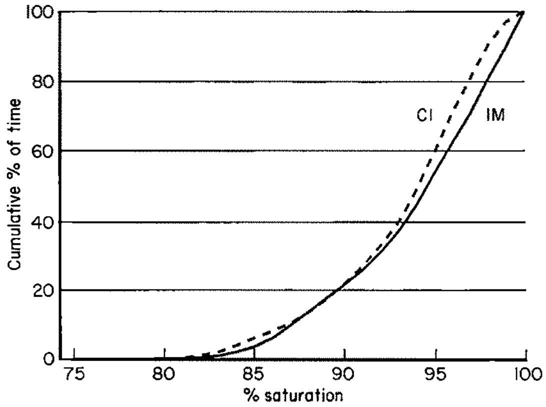

Fig. 3. Time spent at various saturation levels. The vertical axis shows proportion of time at or below the saturation level shown on the horizontal axis. No saturation below 75% was recorded.

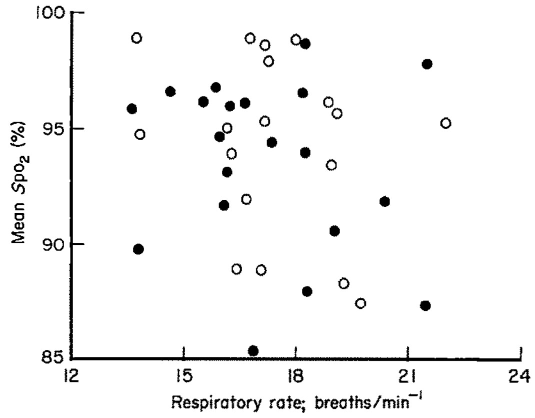

Fig. 4. Relationship between mean respiratory rate and mean saturation; open circles (IM), closed circles (CI). Full respiratory data were missing on two patients in the CI group.

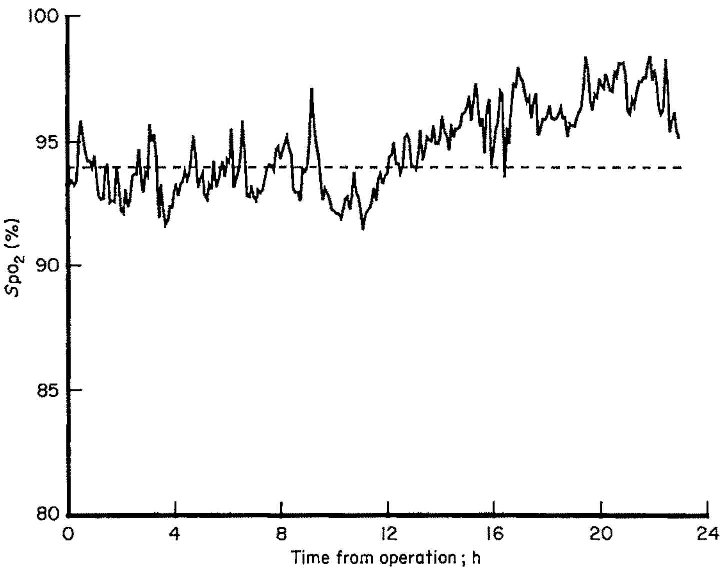

Fig. 5. The 24-h tracing of patient number 28 who received intramuscular morphine is shown. Measurement was commenced at 1700 h real time (Time = 0 h), and shows a typical nocturnal desaturation profile with improvement the next morning.

Volunteers, exposed to short periods of hypoxia produced by a decompression chamber, showed impairment of short-term memory [14], whilst patients with sleep apnoea, exhibiting nocturnal hypoxaemia (mean $Spo_2 = 76\%$), showed significant impairment of general intellectual ability, concentration, hand–eye coordination, rapid mental manipulation and both long- and short-term memory [15].

The results of this study suggest that pre-operative Spo_2 values may have predictive value for postoperative hypoxaemia when combined with other factors such as age, rate of opioid administration and mode of administration. Wheatley *et al.* [7] showed that a value of $Spo_2 < 94\%$ for more than 6 min.h^{-1} pre-operatively was a strong predictor of postoperative hypoxaemia with IM, epidural and PCA for analgesic therapy. Whilst we have suggested that a combination of factors may have predictive value for postoperative desaturation, the adjusted R^2 value (0.32) for the prediction equation indicates that this model is able to explain only about one third of variability in postoperative desaturation. Despite showing the importance of route of delivery of analgesic, patient's age and pre-operative desaturation profile, there are still many unrecognised and possibly important factors that account for this postoperative hypoxaemia. At present a case for oximetric evaluation of all patients in the peri-operative period can be made. Savings in equipment cost and nursing time may become possible when more sensitive predictors of postoperative hypoxaemia permit identification of high risk patients.

The limitations of using respiratory rate as an accurate predictor of respiratory depression and hypoxaemia have again been highlighted. Using observation only, even experienced intensive care unit personnel repeatedly overestimated tidal volume in ventilated patients [16] when compared with direct measurement by respiratory inductance plethysmography. Similarly, Kory *et al.* [17] showed the poor correlation between nurse observation and actual respiratory rate and suggested that the pattern and type of ventilation were clinically more important than the numerical rate. We have confirmed the findings of Wheatley *et al.* [7] and Catley *et al.* [18], showing that mean respiratory rate does not correlate with mean desaturation, hence the emphasis still placed on respiratory rate as an indicator of respiratory depression (i.e. an ability to respond effectively to hypoxia and hypercarbia) and opioid overdose may be misplaced.

Review of graphs of saturation versus real-time (Fig. 5) revealed a consistent pattern of increased frequency and severity of hypoxaemic episodes during the early morning hours. It is known that the combination of sleep and opioid administration are synergistic in producing respiratory depression. The study by Wheatley *et al.* showed that desaturation was more common at night whilst Catley *et al.* noted that patients receiving morphine had more frequent periods of desaturation than those having regional analgesia and that these occurred mostly during the night [18]. It was concluded that sleep, which is known to depress intercostal and upper airway musculature, along with morphine which also preferentially depresses the rib cage contribution to tidal volume, may act synergistically to increase upper airway obstruction and diminish ventilatory effort [19]. Alteration of normal sleep patterns was studied by Knill *et al.* [20] in patients presenting for gastroplasty and cholecystectomy. Broken sleep patterns were evident on the first night following the operation, with suppression of slow wave sleep, and elimination of rapid eye movement (REM) sleep. During the next 3 nights there was an increase in REM sleep, distressing dreams and nightmares, which were associated with altered breathing patterns and hypoxaemia along with increases in heart rate and blood pressure.

Because the present study was a survey and not a randomised trial, any differences identified between the groups could be due to factors other than mode of administration of morphine. However, as most other characteristics were similar in the two groups, we ascribe differences in outcome measures to the different modes of administration. Pain score measurements would indicate that the quality of analgesia was superior in those patients receiving CI analgesia compared to IM administration. This is an important consideration, as inadequate pain relief can lead to diaphragmatic splinting, reduced FRC and impaired gas exchange whereas effective coughing, deep breathing and increased FRC and $FEV_{1.0}$ are associated with optimal analgesia. A recent survey of postoperative pain relief from our institution revealed how little morphine prescribed to be given intramuscularly as required was actually administered; on average less than 1 mg.h^{-1} [21]. Following these findings pain after surgery is now routinely monitored every hour and this has been shown to increase the dose of morphine received by the intramuscular route [22]. Thus these results are representative of the best treatment for each group currently available in this hospital.

In conclusion, we have found that despite the current concern over respiratory depression following PCA and opioids administered *via* the neuraxis, the traditional methods of opioid delivery are associated with frequent and often prolonged periods of desaturation. These periods are related to the dose rate and method of opioid administration, age of patient and pre-operative episodes of desaturation. Intermittent measurement of respiratory rate as an indicator of respiratory depression has again been shown to be of little value and brings into question its role in postoperative patient surveillance. Further work is needed to identify with greater accuracy risk factors associated with postoperative hypoxaemia. Just as pulse oximetry is now regarded as mandatory during anaesthesia, current research may yet dictate that it has an essential role, both pre- and postoperatively.

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Influence of converting enzyme inhibition on isoflurane-induced hypotension for cerebral aneurysm surgery

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Summary

Twenty-five patients (aged 18 to 72 years), who recovered after the first bleed from a cerebral aneurysm, were operated on under neuroleptanaesthesia. Isoflurane was added to induce hypotension. It was found that the required hypotension (51 (SEM 1) mmHg) could be obtained and maintained at much lower isoflurane concentrations (less than 1%) after blockade of the angiotensin converting enzyme activity by enalaprilat (2.5 mg i.v.) than without such inhibition. During the hypotension which lasted 78 (SEM 10) min, only minor adjustments of the isoflurane concentration (0.70 (0.04%) were needed. The desired level of hypotension was obtained with preservation of the cardiac output and without tachycardia. No resistance to the blood pressure lowering effect of isoflurane was observed. On recovery from anaesthesia, a small increase of blood pressure above control values was seen in 16 patients and was easily reversed by small doses of clonidine (mean total dose: 220 (61) µg). The operative conditions were excellent and the postoperative recovery was uneventful and complete in 23 patients.

Key words

Blood pressure; hypotension.
Anaesthetics, volatile; isoflurane.
Pharmacology; enalaprilat.
Surgery; neurological.

Isoflurane in an inspired concentration of less than 2% produces a 20–40% lowering of the mean arterial blood pressure. This results mainly from a decrease in peripheral resistance, while the cardiac output is only slightly reduced [1–3]. This response led Lam and Gelb [4] to use isoflurane as an anaesthetic and hypotensive agent in cerebral aneurysm surgery. Subsequent studies confirmed a small reduction in cardiac output [5–6] but some reported a significant decrease [7]. Moreover, large individual variations in sensitivity frequently require isoflurane concentrations of 4% and higher to produce adequate hypotension [8, 9]. This has led to the use of combinations of isoflurane with other hypotensive agents such as clonidine [9].

Induced hypotension provokes increases in plasma renin activity (PRA) [7, 10] and consequently in angiotensin$_2$ (A$_2$) concentrations.

Angiotensin$_2$ has its own vasoconstrictive effect and potentiates both central and peripheral effects of sympathetic activation on the cardiovascular system [11]. Accordingly, it can be expected that inhibition by an angiotensin converting enzyme (ACE) inhibitor will attenuate the response to sympathetic activation and reduce the requirement of isoflurane during cerebral aneurysm surgery, and perhaps also the incidence of resistance to its hypotensive effects. Beneficial effects of ACE inhibition during sodium nitroprusside hypotension have been well documented [12–15].

In this study we report ACE inhibition during isoflurane induced hypotension.

Methods

After ethics committee approval and written informed consent, 25 consecutive patients, 18 women and seven men (mean age 43 years, 18–72 years; mean weight 65 (SEM 2) kg), who had completely recovered from a subarachnoid haemorrhage after a first bleed from a cerebral aneurysm, were studied. All patients received nimodipine (2 mg.h^{-1}) from the day of admission to reduce morbidity from cerebral vasospasm [16]. Premedication, diazepam (10 mg i.m.) and atropine (0.5 mg i.m.), was given 1 h before induction of anaesthesia. A small dose of fentanyl (0.1 mg i.v.) was given to attenuate the hypertensive reaction to tracheal intubation. Anaesthesia was induced with thiopentone 5 mg.kg^{-1}. On loss of consciousness, pancuronium (0.06 mg.kg^{-1}) was given intravenously. After tracheal intubation a loading dose of fentanyl (7–10 µg.kg^{-1}) was given and a continuous infusion of fentanyl (5 µg.kg^{-1}.h^{-1}) was started and given throughout the entire operation. The patients were hyperventilated to a Paco$_2$ of 4–4.6 kPa (33% 0$_2$/67% N$_2$O). Droperidol was given in increments of 0.1 mg.kg^{-1} (total dose 0.25 mg.kg^{-1}). Operations were performed in the supine or lateral position and a subarachnoid catheter was inserted at L$_{2\text{-}3}$ to permit lumbar cerebrospinal fluid drainage. Monitoring included body temperature, electrocardiogram and end-tidal CO$_2$ concentrations.

After induction of anaesthesia a radial or femoral artery cannula was inserted for arterial pressure monitoring. A 7 F triple lumen thermodilution balloon catheter was inserted through a subclavian vein into the pulmonary artery. Maintenance intravenous fluids (Ringer-lactate) were given (150 ml.h^{-1}); blood loss was replaced by whole blood and a polygeline solution (3.5%).

Enalaprilat (Merck, Sharp & Dohme) was injected intravenously in a dose of 2.5 mg 60 min before hypotension was anticipated.

After opening of the dura, isoflurane was administered with an inspiratory concentration of 1% to induce hypo-

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Table 1. Haemodynamic and laboratory values expressed as mean, SEM ($n = 25$).

	Control	ENAL	Isoflurane hypotension		Posthypot	15'post N_2O	12 h ENAL	24 h ENAL
Plasma renin activity; $ng.ml^{-1}.h^{-1}$	9.9 (2.3)	24.8 (5.1)*	31.4 (5.3)*	32.9 (5.5)*	33.2 (6.1)*	29.7 (6.0)*	11.2 (2.8)	4.9 (1.2)*
Angiotensin converting enzyme activity; $U.l^{-1}$	179 (20)	24 (12)†	5 (1)†	11 (3)†	8 (2)†	15 (3)†	68 (10)*	139 (9)*
$Angiotensin_2$; $pg.ml^{-1}$	53 (14)	27 (14)†	19 (6)†	18 (5)†	12 (2)†	16 (3)†	17 (5)†	13 (3)†
Mean arterial pressure; mmHg	78 (3)	65 (3)*	51 (1)†	52 (1)†	72 (2)	80 (2)	86 (3)	91 (3)†
Cardiac output; $l.min^{-1}$	4.0 (0.4)	4.5 (0.4)	4.5 (0.4)	4.5 (0.4)	5.1 (0.4)*	5.8 (0.5)*	5.9 (0.3)†	5.9 (0.3)†
Heart rate; min^{-1}	68 (3)	65 (4)	70 (4)	67 (3)	67 (3)	67 (3)	68 (2)	72 (5)
Stroke volume; ml	62 (6)	73 (8)†	68 (6)	70 (5)	77 (6)†	89 (6)†	84 (4)†	86 (5)†
Systemic valvular resistance; $dyn.s.cm^{-5}$	1750 (164)	1300 (106)*	1011 (83)†	1002 (71)†	1148 (91)†	1186 (90)†	1219 (77)†	1270 (80)*
Fentanyl; $\mu g.l^{-1}$	3.85 (0.37)	3.96 (0.32)	4.18 (0.30)	4.00 (0.31)	3.38 (0.22)	2.39 (0.22)	1.53 (0.30)*	0.69 (0.25)*

Control = after induction of anesthesia; ENAL = 30 min after enalaprilat; Posthypot = after stopping isoflurane; 15'post N_2O = 15 min after stopping N_2O; 12 h ENAL = 12 h after enalaprilat; 24 h ENAL = 24 h after enalaprilat. Significantly different from control: $^*p < 0.05$; $^\dagger p < 0.01$.

tension. As soon as a mean arterial pressure (MAP) of 50 mmHg was reached the isoflurane concentration was decreased (0.70 (0.04%) in the entire group. During hypotension, which lasted 78, SEM 10 min, only minor adjustments of the isoflurane concentration were needed. After the aneurysm was clipped, the isoflurane was stopped. After skin closure, nitrogen was substituted for N_2O and sedation was maintained by a gradually decreasing fentanyl infusion. An infusion of cristalloid additional to the basal fluid requirement of 150 $ml.h^{-1}$, was started after the hypotension to increase preload, stroke volume, and hence blood pressure. If, on recovery, blood pressure increased by more than 10 mmHg above the MAP measured on the ward before operation, a clonidine infusion (0.75 mg in 250 ml glucose 5%) was started. Sixteen patients needed clonidine (mean total dose: 220 (61) μg).

After surgery the lungs of all patients were ventilated for 10 SEM 2 h to avoid hypoxia and CO_2 retention and to permit the equilibration of plasma and cerebrospinal fluid bicarbonate after several hours of hyperventilation. When the blood pressure was stable, the fentanyl was stopped and the patients were allowed to breathe spontaneously. If the F_{ECO_2} did not increase extubation followed. Mean arterial pressure (MAP), mean pulmonary artery pressure (MPAP), pulmonary artery wedge pressure (PAWP), central venous pressure (CVP) and cardiac output (Q_T) (measured in triplicate by thermodilution) were recorded.

From these the systemic vascular resistance

$$\left[\mathrm{SVR} = \frac{(\mathrm{MAP}-\mathrm{CVP}) \times 79.9}{Q_T}\right]$$

was calculated.

Arterial blood gas analysis was performed. Angiotensin converting enzyme activity (ACEA) was assayed colorimetrically [17]; plasma renin activity, $angiotensin_2$ and plasma fentanyl concentrations in arterial blood were measured by radioimmuno assay [18, 19].

Blood samples and cardiovascular parameters were measured (1) after induction of anaesthesia = control; (2) 30 min after injection of enalaprilat; (3) at the beginning and (4) at the end of the stable hypotension of 50–55 mmHg; (5) after stopping isoflurane when the MAP had returned to the control value; (6) 15 min after stopping N_2O; (7) 12 h and (8) 24 h after enalaprilat injection.

Values were analysed by Friedman two-way analysis of variance by ranks for overall differences, followed by Wilcoxon matched-pairs signed-ranks test when appropriate (comparison between experimental periods). A p value of < 0.05 was cconsidered statistically significant.

Results

The data (mean, SEM) of the different parameters are reported in Table 1.

The renin-angiotensin system. Within 30 min after the injection of 2.5 mg enalaprilat, a sharp decrease of ACEA and plasma A_2, together with an increase in PRA, was seen in all patients. These changes persisted throughout the operation; they returned progressively to normal in the postoperative period.

Cardiovascular variables. After induction of anaesthesia (control period), in most patients there was a slight decrease in both MAP and HR, with respectively 11 (SEM 3) mmHg and 5 (SEM 4) $beat.min^{-1}$.

Within 30 min after the injection of enalaprilat and before the start of isoflurane hypotension, MAP had reduced by approximately 12% (mean). SV was slightly increased while a significant reduction of the SVR of about 25% (mean) was observed in all patients. The heart rate was unchanged.

After opening the dura, the reduction of MAP to 51 (SEM 1) mmHg was obtained and maintained with a mean isoflurane concentration of 0.70 SEM 0.04%. MAP reduction in all patients resulted from a further decrease of the SVR, while cardiac output, heart rate and SV were maintained in most patients and throughout the hypotensive period at the prehypotensive levels.

The hypotension was maintained according to the operative requirements during 15 to 180 min (mean 78 SEM 10 min).

After stopping isoflurane, MAP returned within 20 min to the prehypotensive levels and reached in most patients the values of the control period before the administration of enalaprilat. This was explained by both an increase of SVR and of cardiac output. During the postoperative period, MAP and HR returned progressively to the values before induction of anaesthesia. Cardiac output and stroke volume were in most patients higher and SVR lower than in the anaesthesia period before isoflurane administration. $P\text{a}CO_2$ and pH, $[HCO_3^-]$, haemoglobin and haematocrit remained stable during the whole observation period. Plasma fentanyl concentrations were 4.0 (0.3) $\mu g.l^{-1}$ during the operation.

Discussion

For safe clipping of a cerebral aneurysm induced hypotension is still commonly used. Sodium nitroprusside continues to be used frequently for induced hypotension [20]. There are several possible adverse reactions, such as reflex tachycardia [21], rebound hypertension [22], an increase in intrapulmonary shunting and deadspace [23], and cyanide-thiocyanate toxicity [24]. Some of these disadvantages were reduced, but not totally eliminated when an ACE inhibitor was administered before the infusion of sodium nitroprusside [12–15].

Isoflurane is currently favoured as an agent for induced hypotension with the advantages of easy administration, metabolic stability, rapid onset and rapid recovery [4]. However, induction of profound hypotension requires in most cases quite a high isoflurane concentration, and many patients are isoflurane resistant [8, 9]. An increase of the A_2 concentration can be anticipated since an increase in PRA has been shown during isoflurane induced hypotension [7, 10].

To block the possible effects of increased A_2, ACE inhibition was performed to augment isoflurane hypotension. An ACE inhibitor was administered for its specific inhibition of A_2 formation. The possible adjuvants have specific disadvantages. A reduced cardiac output is observed with central α_2-adrenoceptor agonists (e.g. clonidine), β-blocking agents and calcium antagonists [25–28], which can compromise cerebral blood flow during controlled hypotension [29]. An increase in catecholamines is seen with peripheral α-receptor blocking agents (e.g. phentolamine) and the newest developed combined α_1-receptor blocking and central 5-hydroxytryptamine agonistic agent urapidil [30, 31]. Because circulating catecholamines may increase brain ischaemia [32], these agents could be detremental during hypotension.

The biologically active metabolite of enalapril was injected intravenously, permitting an exact timing of the onset of the ACE inhibition and an optimal dosage to obtain complete ACE inhibition.

Enalaprilat was given in a dose of 2.5 mg, because a pilot study indicated that this dose resulted in nearly total inhibition of angiotensin converting enzyme activity. This was confirmed during this study (see Table). The dose of 2.5 mg enalaprilat i.v. is consistent with the findings by Biollaz *et al.* [33] who described 100% inhibition of the ACE activity following a single oral dose of 10 mg enalapril. Enalapril is about 60% absorbed and about 60% hydrolysed to the active metabolite [34].

That this approach is successful is proven in the present study, as stable hypotension was obtained in all patients within 10 min with an initial inspiratory concentration of only 1% isoflurane, whereas the hypotension level was smoothly maintained for 78 SEM 10 min with a rather low concentration (0.7 SEM 0.04%).

Throughout the operative and postoperative period, A_2 levels remained very low while PRA showed an important increase. It has been shown that ACE inhibition reduces the potentiating effects of A_2 on the pressor reactivity to sympathetic activation [11]. It can thus be hypothesized that the low A_2 concentrations not only excluded direct effects of A_2 on the cardiovascular system, but also prevented its potentiating effects on the sympathetic system. The direct hypotensive effects of isoflurane are less likely to be reversed by reflex sympathetic activity under ACE block so that the hypotension of 50 mmHg can be obtained with a low isoflurane concentration.

With the low isoflurane concentrations the low MAP of 50 mmHg was the result of a decreased vascular resistance while both stroke volume and cardiac output were, compared to the prehypotension period, well maintained, without tachycardia. At concentrations of 1% or less, isoflurane decreases the metabolism and the oxygen needs of the brain [35], while it does not interfere at this concentration with the cerebral autoregulation [36–38].

It has, moreover been shown that ACE inhibition shifts the lower limit of autoregulation 10–15 mmHg downwards, offering additional brain protection during hypotension [39].

On stopping isoflurane, recovery of MAP occurred within approximately 20 min. On emergence from anaesthesia, stress-mediated activation of the sympathetic system normally tends to increase SVR and MAP [40]. In this study an increase of blood pressure above normal control level was seen in 16 patients. The blood pressure rise was small compared to the more than 20% increase which we previously observed in our institution after intracranial surgery. In addition the incidence of hypertension (64%, 16 of 25 patients) and the magnitude of the hypertension ($< 20\%$) are lower than reported by Gibson *et al.* [41], respectively 90% and $> 20\%$. The small increase in blood pressure in the present study was easily neutralized by small doses of clonidine, probably because the A_2 concentrations at that time were still very low.

In conclusion, this study suggestes that the addition of ACE inhibition (2.5 mg enalaprilat i.v.), makes it possible to obtain and maintain the desired level of hypotension with an isoflurane concentration of 1% or less, with preservation of the cardiac output and without tachycardia or tachyphylaxis.

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Central venous access in children via the external jugular vein

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Summary

Sixty-two children undergoing cardiac surgery were surveyed for the presence of external jugular veins. When present, these were used as a route for central venous catheterisation using a 'J' wire Seldinger technique. Only 54% of attempted insertions were successful but the results support greater efficacy in older children.

Key words

Veins; jugular, external, cannulation.

The external jugular vein (EJV) provides a safe and reliable route for central venous access in adults especially where a 'J' wire technique is employed [1,2]. A lower success rate was reported in a small series of children and showed no correlation with patient size [3]. We aimed to assess the suitability of this approach in children in a larger paediatric series.

Method

The presence of EJVs was determined in children presenting for cardiac surgery. After induction of anaesthesia, the child was tilted 15° head down and the EJV was cannulated with a 20 G Abbocath cannula, using full aseptic technique. A J-shaped guidewire (radius of curvature of $J = 3$ mm) was then inserted into the cannula and manoeuvred into a central vein. Finally, after removal of the short cannula, a 22 G hydromer-coated polyurethane catheter was advanced over the guidewire and secured in place. Satisfactory placement was ascertained initially by aspiration of blood through the catheter and after the procedure was confirmed by chest radiography. Duration *in situ* and any complications were noted. All central line tips were sent after removal for bacterial culture.

Results

The children's range of age and weight are illustrated in Figures 1 and 2. The mean age was 41 months and mean weight was 13.9 kg. Twenty-nine subjects were male and 33 were female. Fifty-eight of the 62 subjects (93.5%) had one or more visible EJV and initial cannulation was successful in 50 children (80.6%). Only 33 'J' wires (53.2%) were successfully manipulated into a central vein. Catheters passed easily over the 'J' wires, but two were subsequently found to be malpositioned. In both of these cases the catheters had passed in a cephalad direction along the internal jugular vein, one ipsilaterally, the other contralaterally. The ages, in years, of the successes and failures are shown in Fig. 3, and suggest increased success with age. This was confirmed when the ages in months were compared by calculating the Spearman Rank Correlation Coefficient ($r_s = 0.84$) which showed that age had a statistically significant effect ($p < 0.001$) upon success. This result is more easily appreciated by comparing the success rate in those subjects less than 3 years old (37%) and those above this age (71%). Despite all cannulations being performed by the same anaesthetist, the success rate did not improve with greater experience of the technique over the course of the study.

No pneumothorax or carotid puncture occurred. *Staphyloccoccus albus* was cultured from three of the catheter tips, but none of the children had evidence of systemic sepsis. The duration that successful cannulations remained *in situ* ranged from 4 h to 4 days.

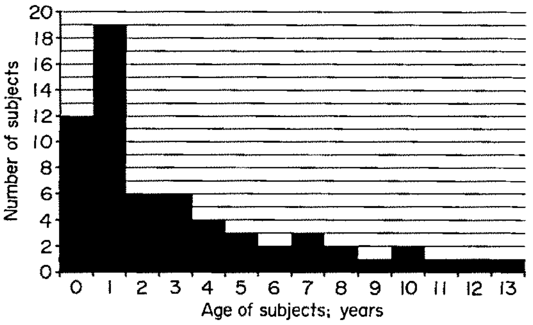

Fig. 1. Distribution of subjects according to age.

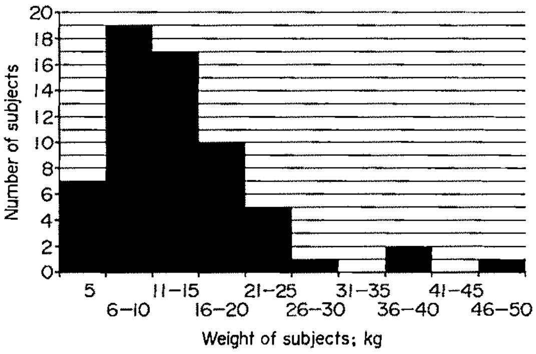

Fig. 2. Distribution of subjects according to weight.

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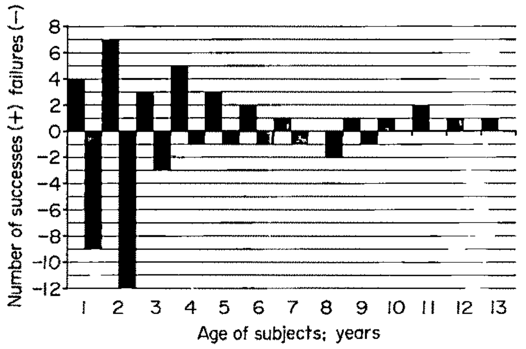

Fig. 3. The ages in years of the successful and failed cannulations.

Discussion

Our results show an overall 54% rate for successful central venous cannulation. This is similar to that found by Humphrey and Blitt [3] who quoted a rate of 59% of actual attempts. However, in our study we found a positive correlation between successful cannulation and patient age. Our smaller and lighter subject population may therefore explain our slightly lower success rate. Previous authors [3,4] have suggested that a smaller radius of curvature 'J' wire would be beneficial in children, allowing the 'J' to reform in smaller vessels and hence allow optimal utilisation of the basic 'J' wire principle. As 3 mm 'J' wires have been shown to be optimal in adults [5] we would anticipate that 1.5 mm radius 'J' wires, available since the completion of our series, would be more suitable for most children.

We believe that the technique that we have described is simple and safe to perform. Failure to cannulate a central vein may still provide good peripheral venous access and the patient is already prepared for subsequent internal jugular vein cannulation. With our equipment, we gained central venous access in 71% of attempts in children over 3 years of age. With the smaller 'J' wires now available this acceptable rate could perhaps be improved and extended to include younger patients.

Acknowledgements

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Anaesthesia, 1992, Volume 47, pages 267–268

Adult respiratory distress syndrome following cardiopulmonary bypass: incidence and prediction

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Summary

The outcome of adult respiratory distress syndrome complicating cardiopulmonary bypass has changed little in recent years. A retrospective, case-controlled study was designed to assess the incidence of the adult respiratory distress syndrome in these circumstances and the extent to which it could be linked with pre and peri-operative predictive factors. Eleven patients who developed the syndrome out of 840 who underwent cardiopulmonary bypass over a 9 month period were compared with 53 controls matched for sex, operation and surgeon. The incidence of adult respiratory distress syndrome and its mortality were 1.3% and 53% respectively. Significant predictors were a high intra and postoperative intervention score, the total volume of blood pumped during bypass (> 300 1) and age (> 60 years). These risk factors should alert the clinician to the possibility of severe postoperative pulmonary complications.

Key words

Surgery; cardiac.
Complications; adult respiratory distress syndrome.

The mechanisms underlying the adult respiratory distress syndrome (ARDS) remain unknown. The syndrom is characterised by high permeability pulmonary oedema consequent upon endothelial cell damage resulting in refractory and often terminal hypoxaemia [1]. The associated mortality approaches 65% and has changed little in the last 20 years [2]. ARDS may result from a wide variety of direct and indirect insults to the lung, but only a small proportion of those patients at risk develop the full-blown syndrome [3]. Predicting these therefore assumes considerable clinical importance. Patients undergoing surgery involving cardiopulmonary bypass (CPB) represent one of the largest groups at risk with respiratory compromise a common explanation for a prolonged postoperative stay in the intensive care unit (ICU). It has been suggested that lung injury almost certainly complicates all cases, in the form of increased pulmonary capillary permeability, accumulation of interstitial fluids, leucocytosis and fever [4]. In a small study in the early 1980s the incidence of frank ARDS following CPB was reported as 1.7% with a mortality of 50% [5]. However, the development of improved operative approaches and techniques may have reduced both the incidence and mortality of ARDS since that time.

Consequently, a retrospective, case-controlled analysis was designed in order to assess the incidence of ARDS following CPB and the extent to which this was associated with pre and peri-operative predictive factors.

Methods

Study population. Postoperative intensive care data of all patients undergoing CPB at the Royal Brompton National Heart and Lung Hospital are recorded routinely and all patients developing ARDS have their notes identified. All cases of ARDS (see below) during the period October 1987–July 1988 were reviewed. In our unit, ARDS is diagnosed clinically in patients with (1) refractory hypoxaemia (ratio of arterial oxygen tension to fractional inspired oxygen concentration of less than 20) (2) evidence of diffuse bilateral pulmonary infiltrates on chest radiograph and (3) a pulmonary artery occlusion pressure (PAOP) less than 18 mmHg. In the current study, the diagnosis was confirmed retrospectively using the criteria of Murray *et al.* [6]. Briefly, this involves 'scoring' lung compliance, the fractional inspired oxygen concentration $F\text{IO}_2$, the degree of positive end expiratory pressure (PEEP) utilised and a chest radiograph. A score greater than 2.5 is required before severe lung injury can be diagnosed. For each ARDS patient, five gender, operation and surgeon matched controls were selected and scored identically. In two cases it was possible only to identify four and three controls respectively.

Data collection. In all cases the Murray score was performed for the time that ARDS was diagnosed, or in the case of controls during their stay in the Intensive Care Unit. In both groups, an attempt was made to predict those patients likely to develop ARDS. A scoring system was therefore devised in which one point was awarded for each of four intra-operative interventions: an additional period of CPB, the use of an intra-aortic balloon counterpulsation device, renal dialysis within 24 h of bypass, or ventricular assist device. In separate analyses age, duration of aortic cross-clamp and total pumped blood volume were compared between ARDS patients and their controls. Pump flows were recorded every 10–15 min and the total pumped volume was the product of flow and time on bypass.

Data analysis. Conditional logistic regression was carried out for all data. Relative risk and Chi-squared testing was performed to assess significance with $p \leqslant 0.05$ considered statistically significant.

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Table 1. Patient population: demographic and operative details.

Age	Total pumped volume (l)	Cross clamp time (min)	Intra-operative intenvention score	Outcome
61	106	20	2	Lived
56	246	76	0	Lived
59	420	150	1	Lived
69	82	42	2	Died
73	78	96	1	Lived
44	348	102	1	Died
70	192	33	0	Lived
72	273	41	1	Died
61	177	72	1	Died
71	351	29	2	Died
74	98	31	1	Died

Results

Eleven patients (1 female) developed ARDS out of a total number of 840 patients entering the ICU during the study period giving an overall incidence of 1.3%. None of the control population achieved Murray scores > 2.0. The demographic and peri-operative characteristics of the ARDS group are shown in Table 1. Six of the 11 patients died in the ICU, a mortality of 55%. In the case-controlled analysis, only the intra-operative intervention score significantly predicted risk of developing ARDS (Table 2). However, when all the ARDS patients were compared with all the controls an age greater than 60 years and a total pumped blood volume greater than 300 l were shown to be significant predictors ($p < 0.001$ odds ratio 63 and $p < 0.001$ odds ratio infinity respectively).

Discussion

This study revealed that the incidence of ARDS complicating CPB remains comparable to that described in data collected at least 7 years ago. Secondly, patients with high intra and postoperative intervention scores are much more likely to develop ARDS.

The incidence of ARDS in patients undergoing CPB in our unit was 1.3%. The extent to which this is typical of other centres is unclear, although the Royal Brompton National Heart and Lung Hospital is the biggest single unit undertaking these procedures in the United Kingdom. Furthermore, the incidence appears to have changed little in recent years, remaining almost identical to the figure of 1.75% in 253 cases described by Fowler *et al.* [5]. Nevertheless, the current study was undertaken in a tertiary referral centre in which the patients often require complex and high-risk surgery. As our ICU records were only available from 1987, we do not know if the incidence of ARDS has changed over the same time period.

Table 2. Statistical analysis of predictive factors for ARDS.

Parameter	Coefficient (SE)	p-value	Odds ratio
Age	0.78 (0.05)	0.15	1.09
Pumped volume	0.006 (0.01)	0.48	0.99
Aortic cross clamp time	0.026 (0.02)	0.30	1.03
intra/postoperation Intervention score	3.48 (1.46)	0.02	32.4

Existing ICU severity scoring systems such as APACHE II have been shown to be inappropriate for CPB patients [7] and our intra-operative intervention score was devised by consultants accustomed to providing care for CPB patients. The parameters selected tended to identify patients who had undergone lengthy or complicated surgery and who were therefore exposed to any adverse effects of CPB for prolonged periods. Our findings suggest that it is possible to predict some of the cases of ARDS complicating CPB from clinical observations with those aged over 60 years with high pumped blood volumes (> 300 l) most at risk. If prophylactic measures for ARDS become available such factors might help identify a group most likely to benefit.

Acknowledgments

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Contamination of piped oxygen supplies

We were interested in the correspondence by Dr Shaw and colleagues concerning failure of oxygen quality (*Anaesthesia* 1991; **46:** 887–8) A similar event occurred in this hospital in June of this year.

To summarise, an oxygen quality failure occurred in the early evening in the operating theatre during the course of an emergency laparoscopy for suspected ectopic pregnancy. The event was detected by both pulse oximetry and inspired oxygen monitoring (nadirs 66% and 11% respectively). Anaesthesia was continued using cylinder oxygen, and a new anaesthetic machine; the patient recovered unharmed. Oxygen outlets in the operating suite, a complex of seven theatres, were checked by the engineering staff, who were called out immediately. The engineer found no fault. Further anaesthesia was continued using pipeline oxygen. There were no other untoward events that evening.

The following morning, a similar event occurred in the same operating theatre. This list involved an 'early start' (0815 h) and no other operating theatres were working at that time. Anaesthesia was continued using cylinder oxygen. Oxygen pipelines in two other operating theatres, and their anaesthetic rooms, were found to be delivering a low concentration of oxygen. Subsequent scheduled operating lists (fortunately not started) were cancelled. The patient involved was again unharmed.

The intensive therapy unit (ITU), although a separate 'zone', receives oxygen from a spur in the pipeline from the operating theatre complex. It had been empty for approximately 12 h before the first incident and had remained empty overnight. All the oxygen outlets in the ITU delivered varying levels of oxygen. The most distal outlet delivered 23% oxygen. However, all outlets showed this purity problem to be of a transient nature. We presumed that air had contaminated the pipeline, as a bolus. Unfortunately we obtained no gas sample.

We went through a similar chain of events as in Walton Hospital, during which the entire oxygen pipeline (which supplied the whole hospital) was closed down. Our con-

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tamination appeared restricted to two zones, the main operating theatres and intensive therapy unit. The separate obstetric operating theatre suite had no oxygen failure and was in use during the evening. The obstetric operating theatres lie at the opposite end of the hospital site and receive their oxygen from a different pipeline spur, as does the adjacent neonatal intensive therapy unit. Oxygen analysers were, however, not in use in the neonatal intensive therapy unit, where oxygen purity is assumed.

We learnt a considerable amount during this event and had intended to write a detailed report for possible publication.

Among the lessons learnt were: (1) The declaration of 'safety' of the pipeline was based upon pressure testing only. The anaesthetist quite correctly reported the fault and the engineer tested the pipeline as required. However, the engineer does not check the pipeline for quality, and was under the impression that quality was not a problem. The anaesthetist did not realise that oxygen quality was untested and there was thus a failure of understanding of what a safety check involved. Engineers are not responsible for 'purity', which rests with the pharmacists.

(2) The anaesthetist (a registrar) although reacting 'correctly' in regard to his responsibility to his patient, did not consider the wider implications of the oxygen failure. Furthermore, the apparent transitory nature of the fault did not alert either himself, the engineer, or the operating theatre nursing staff on duty, to the significance of the event. A telephone call to the ITU during the initial event had asked about 'problems' with oxygen. The response had been to confirm that there was no problem with 'pressure'. No indication of a fault in quality was given. Because no patients were in the ITU, no oxygen quality failure was noted (although all patients would have had continuous inspired oxygen and saturation monitoring).

(3) Communication of both the fact and the exact nature of the fault were severely limited. No dissemination of information beyond that described above occurred on the evening of the incident, nor was the incident communicated specifically to the anaesthetic staff on duty the following morning.

(4) In common with most UK hospitals dependent upon pipeline oxygen, our anaesthetic machines are fitted with only one back-up oxygen cylinder. Anaesthesia conducted using a single cylinder machine requires some planning, and severe disruption to all surgery occurred for several days.

(5) Pipeline closure is complex and disruptive. The full implications of a contaminated pipeline only becomes apparent when one audits the number and variety of patients relying on a source of 'pure' oxygen. Nearly 60 patients in the hospital (including five neonates receiving artificial ventilation and 14 adult patients on a single ward) were receiving oxygen at the time the pipeline was declared unsafe. At very short notice, we required, and had to distribute, a large number (50) of additional oxygen cylinders, regulators, cylinder keys, and cylinder trolleys.

(6) Re-opening of a pipeline containing over 500 outlets took 3 days. Each outlet required individual purity checking. We re-opened the pipeline progressively, declaring individual zones 'safe'. This may not be good practice.

In view of our problem, and because we found no definite cause for the quality failure, we have introduced a series of additional safety measures. Among these are: (1) 'Surveillance' oxygen monitoring, where oxygen is continuously bled from three sites on the pipeline. Oxygen concentration is continuously monitored at the sites using fuel cell analysers, shortly to be replaced with paramagnetic analysers; (2) we have increased the number of points at which oxygen pipeline pressure is monitored and/or displayed; (3) we have introduced oxygen analysers into the neonatal intensive therapy ventilator practice. Until this time oxygen–air blenders, with no monitoring of delivered concentration, were in use. Nonmonitoring of inspired oxygen concentration delivered by neonatal ventilators is apparently not unusual in the UK; (4) oxygen analysers, already in routine use in the ITUs, are being replaced with alarmed analysers; (5) oxygen monitoring, at present universal in the operating theatres, is being progressively extended to the anaesthetic rooms.

We consider that the most likely cause of this event was air entering the oxygen pipeline. Like Walton Hospital, we found a slight difference in pipeline pressure between air and oxygen. No faults were found in the pipeline and there was no evidence of sabotage. No recent work had been undertaken on the pipeline and the vacuum insulated evaporator had not been recently filled. We have no evidence to suggest misuse of equipment. All equipment using blenders (e.g. Erica ventilators) was found to be functional, and no equipment had undergone modification.

It is now apparent that universal oxygen quality monitoring is necessary. We cannot trust our pipelines absolutely. We know of at least one other incident reported to the Department of Health. However, the problem has not been widely publicised. We believe that the fault was due to leakage of air into the oxygen pipeline, due to a pressure differential. As is common practice, linking air and oxygen hosing after delivery from wall mounted flow meters etc, (for instance to run ventilators, humidifiers etc in ITU) may be dangerous, and antibackflow devices may be necessary. This will have significant ramifications, well beyond the practices we have introduced in this unit.

South Cleveland Hospital,
Middlesbrough TS4 3BW

P.G. Lawler
P.T.F. Newman

Elective tracheostomy for coronary artery bypass grafting

I read with interest the report by Foster and Clowes (*Anaesthesia* 1991; **46:** 701) regarding the transient use of the laryngeal mask airway (LMA) in a case of unexpected difficult intubation prior to coronary artery bypass grafting. Following repeated attempts at intubation, a LMA was successfully inserted and adequate ventilation achieved. It was deemed inappropriate to use the LMA for further airway management because of the requirements for prolonged, reliable ventilation. However, rather than considering intubation through the LMA, an elective tracheostomy was performed on the grounds that, should further attempts at intubation be successful, subsequent accidental extubation in the ITU would be dangerous. Whilst commending the use of the LMA to secure the airway, some further comment with regard to its use as an aid to intubation and the authors indications for elective tracheostomy is needed.

Firstly, whilst agreeing that it was reasonable to seek an alternate form of airway management, I do not feel that tracheostomy was indicated before at least attempting to use the LMA as an aid to intubation. These techniques have been widely reported and success rates are high [1, 2]. Secondly, to justify a tracheostomy because of concern about accidental extubation is questionable. Tracheostomy carries a significant morbidity and mortality rate [3]. Are the authors suggesting tracheostomy for patients on ITU in whom re-intubation by 'conventional' means would be impossible? Finally, in the unlikely event of accidental extubation in ITU, surely the LMA could be used yet again to secure the airway and aid intubation.

Cairns Base Hospital,
Cairns 4870,
Queensland, Australia

J. Brimacombe

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Rectus sheath and mesosalpinx block for laparoscopic sterilisation

We read with interest the technique of mesosalpinx block for pain after laparoscopic sterilisation described by Smith and his colleagues (*Anaesthesia* 1991; **46:** 875–7). The technique appears very similar to that described by Alexander *et al.* [1], who found that bupivacaine infiltration of the mesosalpinx significantly reduced the pain after Yoon (Falope) ring sterilisation. Our own study that year [2] showed that ring sterilisation was followed by significantly more pain than Hulka clip sterilisation during the first 6 h after operation. The pain associated with the Falope ring presumably arises from infarction of the tubal section drawn into the ring and/or the pull on the mesosalpinx drawn with it. The ring technique also highlights, however, the consequent destruction of a substantial length of the tube, often including the isthmo-ampullary junction, which leads to both functional loss and technical difficulty that undermine the chance of successful reversal of the sterilisation [3]. The ring method also occasionally results in tearing of the tube and mesosalpinx causing bleeding. The clip method is therefore to be preferred for reasons in addition to obviating any need for special analgesic technique.

It would be more valuable to know whether the technique of mesosalpinx injection of local anaesthetic, with its small but potentially dangerous risk of bleeding, offers a benefit : risk advance in the operation of clip sterilisation. It would also be valuable to know whether this local anaesthetic technique reduces significantly the pain which continues for up to 4 days postoperatively and may be caused by gas retention in the abdomen, particularly above the liver. This can be reduced by the simple expedient of leaving a tube drain in the abdomen through the laparoscopy puncture site for a few hours afterwards [4].

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Department of Obstetrics and Gynaecology
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Bristol BS2 8EG

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A problem with the TEC 5 vaporizer

We wish to report a potential problem in the design of the Ohmeda Tec 5 vaporizer which may lead to the sudden loss of the total anaesthetic agent from the vaporizer.

The Tec 5 is the latest addition to the Ohmeda line of anaesthetic agent vaporizers. It offers several distinct advantages over the Tec 4 in terms of ease of use, performance and safety features. In addition, the Tec 5 can accommodate a greater volume of the free anaesthetic agent (225 ml as compared with 90 ml for Tec 4), thus minimising the frequency of filling. Difficulties with filling the Tec 4 vaporizers [1] as well as leakage of anaesthetic agent from the drain port [2] have led to a unique keyed filling mechanism in the Tec 5 version.

During an otherwise uneventful anaesthetic for an orthopaedic procedure in which the patient was breathing spontaneously, the filling port valve was accidentally brushed against whilst the patient's case notes were being picked up from the anaesthetic table top. This flicked open the filling port valve, resulting in a large loss of the anaesthetic vapour, as reconstructed in Figure 1. The filling port valve, which is normally only opened during filling of the vaporizer, is not secured by a locking mechanism during routine use. The simple and obvious consequences of such large leaks include the exposure of the theatre personnel to anaesthetic vapours, loss of an expensive anaesthetic agent, possibility of anaesthesia becoming light, and damage to items on the anaesthetic table top. The potential for disaster is great, including the anaesthetist's

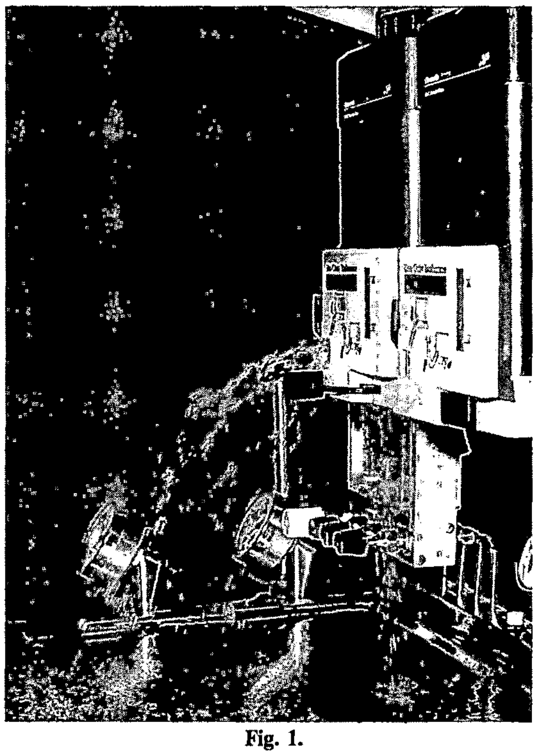

Fig. 1.

eyes being sprayed by a large volume of the anaesthetic agent.

This obvious design fault of the Tec 5 vaporizer needs urgent rectification before a serious accident occurs.

Hammersmith Hospital,
London W12 0HS
A. Rajah
D.A. Zideman

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A reply

Thank you for the opportunity to respond to the above letter. We have supplied in excess of 10 000 Tec 5 Vaporizers worldwide and have received only a small number of reports concerning this flush fitting lever. We are nevertheless reviewing this feature of the design in the light of the comments made.

Ohmeda Anaesthesia Systems,
Steeton
R. Bridges

Dural puncture and epidural catheters

I have been interested in combined epidural and spinal anaesthesia in obstetrics for some years and would support the letter by Hughes and Oldroyd (*Anaesthesia* 1991; **46:** 802). To direct the spinal needle and epidural catheter in different directions is logical and indeed it surprises me that one would not do so. I have practised the same technique as described with the exception of inserting the Tuohy needle in the standard fashion with the bevel directed upwards and the patient in the left lateral position. This necessitates an extra 90° gentle turn caudad and could be a disadvantage over that described by Rawal [1]. In a series of 77 patients employing this method in 1982–83, I must confess to the catheter being inserted intradurally in three patients. One was electively placed following a dural tap on the 180° turn; the other two were mishaps. While one cannot exclude dural entry at the site of spinal needle puncture it does seem unlikely. The use of radio-opaque catheters at that time, with their greater stiffness, indicates a more likely culprit.

Since that early trial, with selective use of the single segment technique and softer clear catheters, I too would allay obstetric anaesthetists' concerns over the potential complications.

Royal Maternity Hospital,
Glasgow
D.J.M. Ferguson

Reference

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Pneumothorax and insertion of interpleural catheters

We would like to comment on a recent modification to the technique for insertion of interpleural catheters (*Anaesthesia* 1991; **46:** 889 and also [1]). Both these modifications are designed to reduce the incidence of pneumothorax produced during insertion of the catheter, which has recently been quoted as 2% [2]. Such attempts to make a technique safer should be congratulated. However, we are uncertain of the need for such modifications as the majority of these pneumothoraces have been very small, clinically insignificant and have resolved spontaneously [3–6]. The only tension pneumothorax reported was produced by using a loss-of-resistance technique [7] which most authorities would not recommend.

Against these modifications is the fact that they make the technique more complicated and cumbersome. The first modification involves manipulation of a three-way tap whilst the end of the Tuohy needle is within the pleural space. By increasing the length of time that the Tuohy needle is in close proximity to the lung and with the probability of increased movement of the tip of the Tuohy needle during manipulation of the three-way tap, there may be an increased incidence of direct injury to the lung. This may be of much greater significance than the entrance of a few millilitres of air into the interpleural space, as occurs using other techniques. The second modification [1] is more time consuming and has significant cost implications.

By using the hanging drop technique first described by Squire *et al.* [8] we believe the volume of air entrained between puncture of the parietal pleura and insertion of the catheter is reduced to a minimum. The only situation in which this may be of significance is when the patient is then going to undergo positive pressure ventilation. We have avoided this problem by inserting the catheters at the end of surgery.

We are concerned that by increasing the complexity of a relatively simple technique this may result in an increase in the incidence of clinically significant pneumothoraces. Perhaps a more important aspect of safety is to ensure that the technique is taught appropriately and that there is adequate supervision of junior staff.

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P.M.S. Dobson
J.E. Peacock

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More on audit

Under the present political climate every anaesthetic department in the country is having to embrace the concept of audit and the problems that may arise in the area of data collection and retrieval. At the same time, the College of Anaesthetists is in the process of encouraging the use of log books as a record of the junior anaesthetist's clinical experience. In Bloomsbury, anaesthetic audit has been operational now for over 2 years in the three main hospitals in the district (UCH, The Middlesex and Elizabeth Garret-Anderson Hospitals) and this has recently been extended across the district to include a further three hospitals.

Up until the end of last year the record of any individual patient undergoing anaesthesia was uniquely identified on our audit cards by entering his/her date of birth. It was originally felt that recording the patient's hospital number posed a number of problems, not only with respect to confidentiality, but also when two or more sets of notes with separate numbers were present, or again when a patient coming quickly to the operating theatre from the Accident & Emergency (A & E) department held a temporary A & E number prior to a definitive set of notes and hospital number being issued.

At the beginning of this year we added to each patient's audit card a slot for a code number relating to the surgical procedure undertaken, in the hope that this would provide not only a convenient entry point for data retrieval on all patients undergoing a particular procedure, but also provide for each junior anaesthetist at the end of his/her job a concise record and printout for log book purposes of all anaesthetics administered. Initially we used code numbers derived from the handbook, *BUPA Schedule of Procedures*, available in all operating theatres [1]. This was soon found to be unsatisfactory. The BUPA schedule, although based on the OPCS Classification, does not reflect accurately the variety of procedures carried out in our hospitals [2]. Some extra codes have been introduced by BUPA themselves and the system basically is employed for the remuneration of surgeons and anaesthetists in the private sector.

We then used the OPCS book itself. For those unfamiliar with it, this is a massive tome of some 240 pages published by HMSO and costing upwards of £17 a copy. It lists and classifies surgical procedures in such a diverse and exact way as to make it too sophisticated for the needs of a junior log book. For example, it lists no fewer than 32 potential classifications of endoscopic procedures on fallopian tubes, which may be of some relevance to the surgeon, but usually means little in terms of variety of anaesthetic technique employed by the anaesthetist. Concern was also felt that during the conduct of an anaesthetic the anaesthetist's attention might be distracted from the patient while searching for the operation code in the desire to complete the record card. In our own department we have now resorted to using short three digit codes from the front section of the OPCS book; however, even this is not completely satisfactory.

Given that some form of computerised coding system is deemed necessary for easy retrieval, the ideal would be to have a coding system of operations or procedures (perhaps based on the OPCS book) which easily identified and reflected accurately in a simple way, the anaesthetic technique involved. It would have to be 'user friendly' in the operating theatre and available to all departments in the country. It might at the same time be useful to our surgical colleagues as they take up the idea of audit. Perhaps the College or the Association might provide a lead in this area.

University College Hospital,
London WC1E 6AU
S.M. Robertson

References

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Failed tracheal intubation in obstetrics — possible audit?

The Confidential Enquiries into Maternal Deaths represent successful medical audit and have contributed to improvements in maternity services in this country. Whilst we must not become complacent, perhaps the time has come to look at other undesirable outcomes, short of the disaster of a maternal death. We feel that we have an opportunity to improve maternal care further by auditing all cases of obstetric failed intubation.

The incidence of failed tracheal intubation in obstetrics has been variously estimated at 1 in 280 [1] and 1 in 300 [2]. If one takes the triennium 1985–87 (the last for which national figures are available) then, assuming the percentage of total maternities delivered by Caesarean section to be 10%, the annual number of Caesarean sections in the United Kingdom is about 74 000 [3]. The number of these procedures carried out under regional anaesthesia varies widely between different units. If we assume that about half of these sections are carried out under regional anaesthesia, this would mean that there are probably 125–150 failed intubations in the United Kingdom each year.

We propose that data regarding these incidents, and, more importantly, the subsequent management of the patients concerned, should be collected nationally. One would anticipate that initial action would follow the 'failed intubation drill' described by Tunstall [4], but subsequent steps (subarachnoid block, extradural block, general anaesthesia with spontaneous ventilation — with or without the aid of devices such as the laryngeal mask or the oesophageal gastric tube airway [5]) would perhaps show more variation.

Therefore we would suggest that a central coordinating body (perhaps a subcommittee of the Obstetric Anaesthetists Association) sets up a prospective survey over a period of a year. The anaesthetist in administrative charge of each maternity unit would be responsible for returning a case report of each incident. The results of the survey would then be published, thus allowing assessment of current schemes of management; this would perhaps enable the formation of agreed protocols for the management of such events so as to minimise both their mortality and morbidity.

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Liverpool L12 2AP
J. Lockie
F. Potter

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Fragmented laryngeal mask airway

At the end of a routine minor orthopaedic procedure, the size four laryngeal mask airway (LMA) was to be removed prior to transfer to the recovery room. Gentle traction on the tube resulted in a clean fracture at the level of the patient's teeth, although he was not biting. A further manual attempt at removal caused a second fragment to break off very easily. The patient, by now getting light, closed his teeth in front of the remaining LMA. It was still possible to hold the jaw open, and using Magill's forceps, several more fragments were broken off before the LMA was successfully removed by grasping the cuff (Fig. 1). The pilot tube was pulled during this procedure and also detached. The patient made an uneventful recovery and at no time did his monitored oxygen saturation fall below 90%.

Examination of the LMA showed the tube to have a normal appearance, but the friability of Cheddar cheese; further fragments were quite easily broken off. Nothing unusual was noticed during insertion of the device. Enquiries in the CSSD revealed that the LMAs were being autoclaved in the recommended manner, but we had no way of knowing how many times each LMA had been autoclaved. It seems that the LMAs were most commonly discarded due to failure of the cuff before other problems could arise.

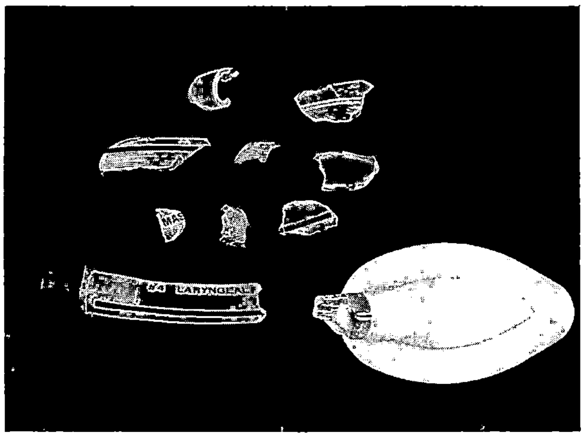

Fig. 1.

We now test our LMAs for elasticity before insertion, and have started to engrave a number on the clear plastic connector inserted in the end of the tube as each new LMA enters use. This number will be logged each time the LMA is autoclaved.

Royal Naval Hospital,
Plymouth PL1 3JY
S.J. Squires

A reply

Thank you for the opportunity of replying to Dr Squires.

The segments of the laryngeal mask used by Dr Squires have been sent to laboratories here and overseas for analysis. Our initial reaction on receiving this laryngeal mask was that damage may have occurred to the airway tube in previous usage. Laboratory findings indicated that postcuring of this silicone airway tube may have been at too high a temperature or too long in duration. Immediate sampling of all stocks has revealed no further defective airway tubes. However, the primary concern is for patient safety and we have issued a letter to all Departments of Anaesthesia warning that great care should be taken in checking laryngeal masks prior to use.

We regret that Dr Squires should have had such an experience and would like to assure all users that as a result even more stringent checks are made on LMs at every stage of manufacture. Further, we are most happy to take enquiries through our distributors Colgate Medical Ltd should anyone have any queries with regards to care, maintenance, handling and pre-use checks of laryngeal masks.

Intavent Ltd,
Reading,
Berkshire RG7 5AH.
K. Woods

A problem with a multilumen catheter

I wish to communicate a problem encountered in this hospital with the use of the Arrow-Howes Multilumen Central Venous Catheterisation Kit, with the Arrow (Raulerson) Safety Syringe. Two patients in this hospital, during preparation for elective vascular surgery, have had inadvertent carotid artery puncture during attempted internal jugular venous cannulation, the arterial puncture being unrecognised until after the insertion of the multilumen catheter. In neither case did the colour of the blood or the ease of aspiration indicate the arterial puncture has occurred.

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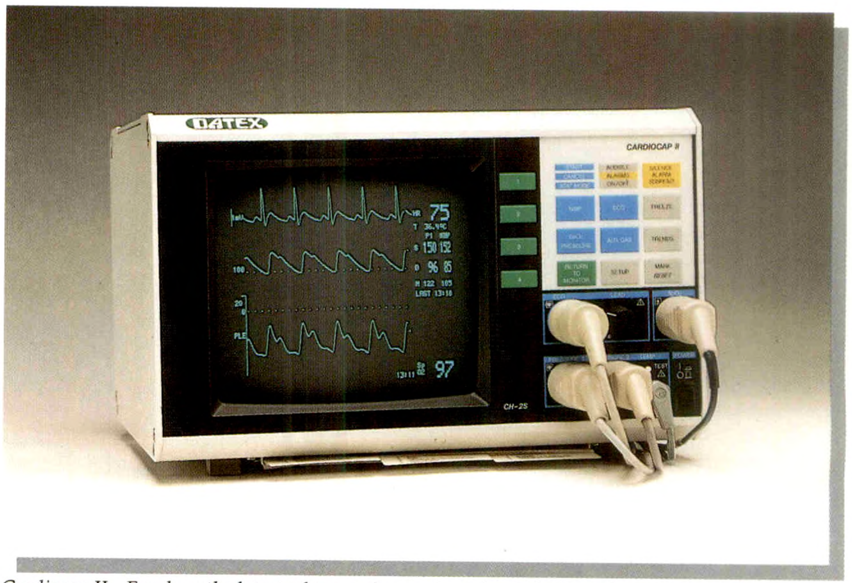

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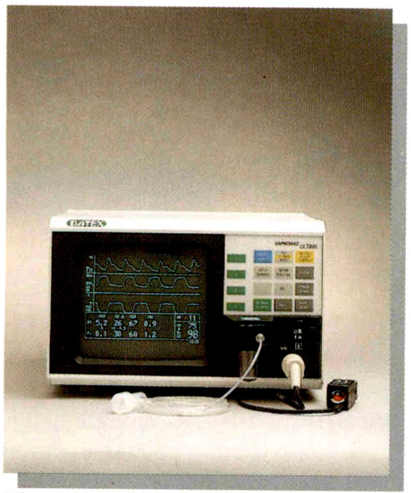

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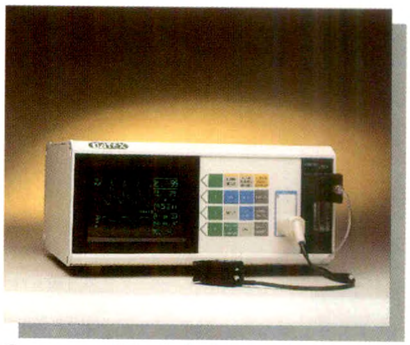

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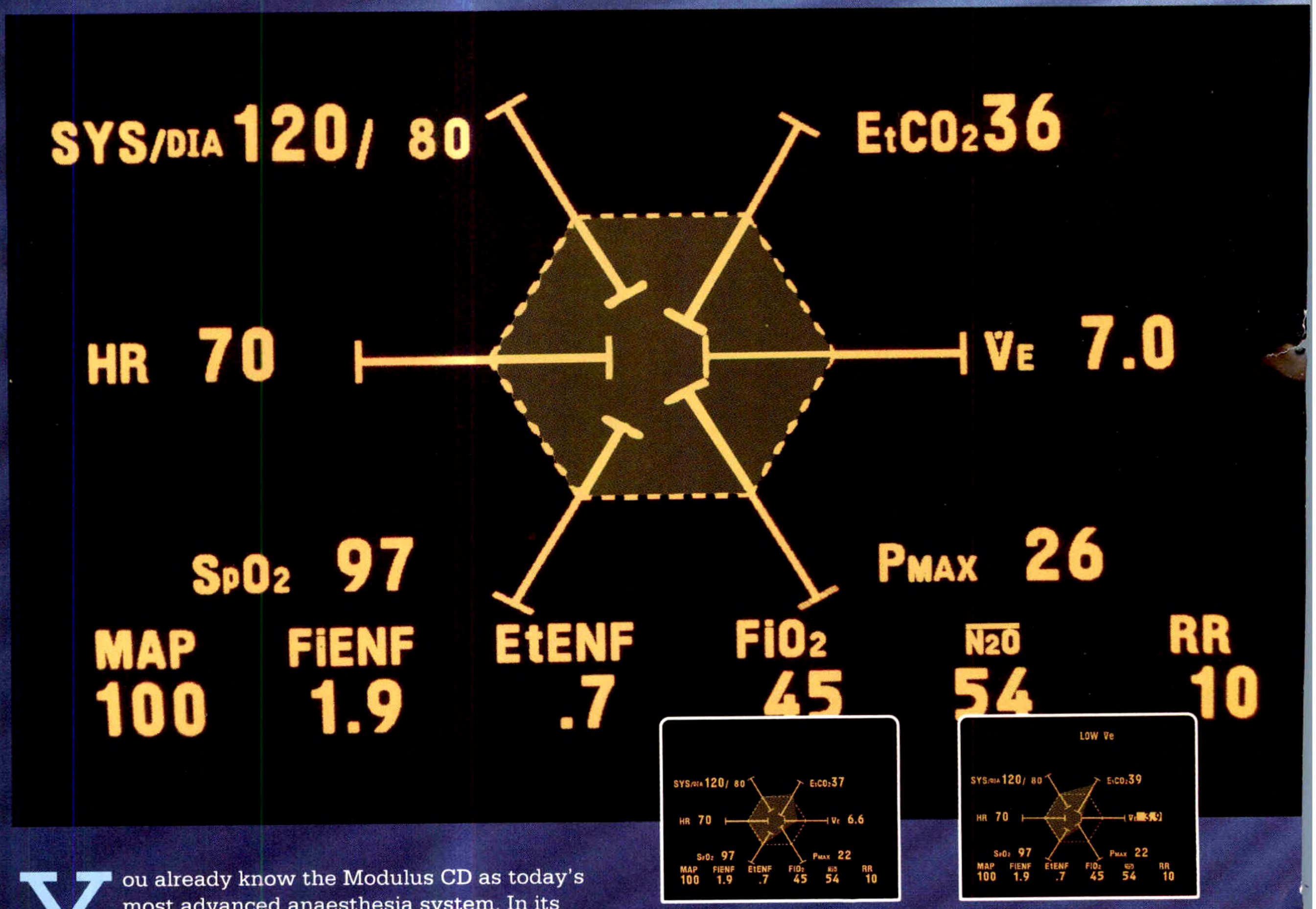

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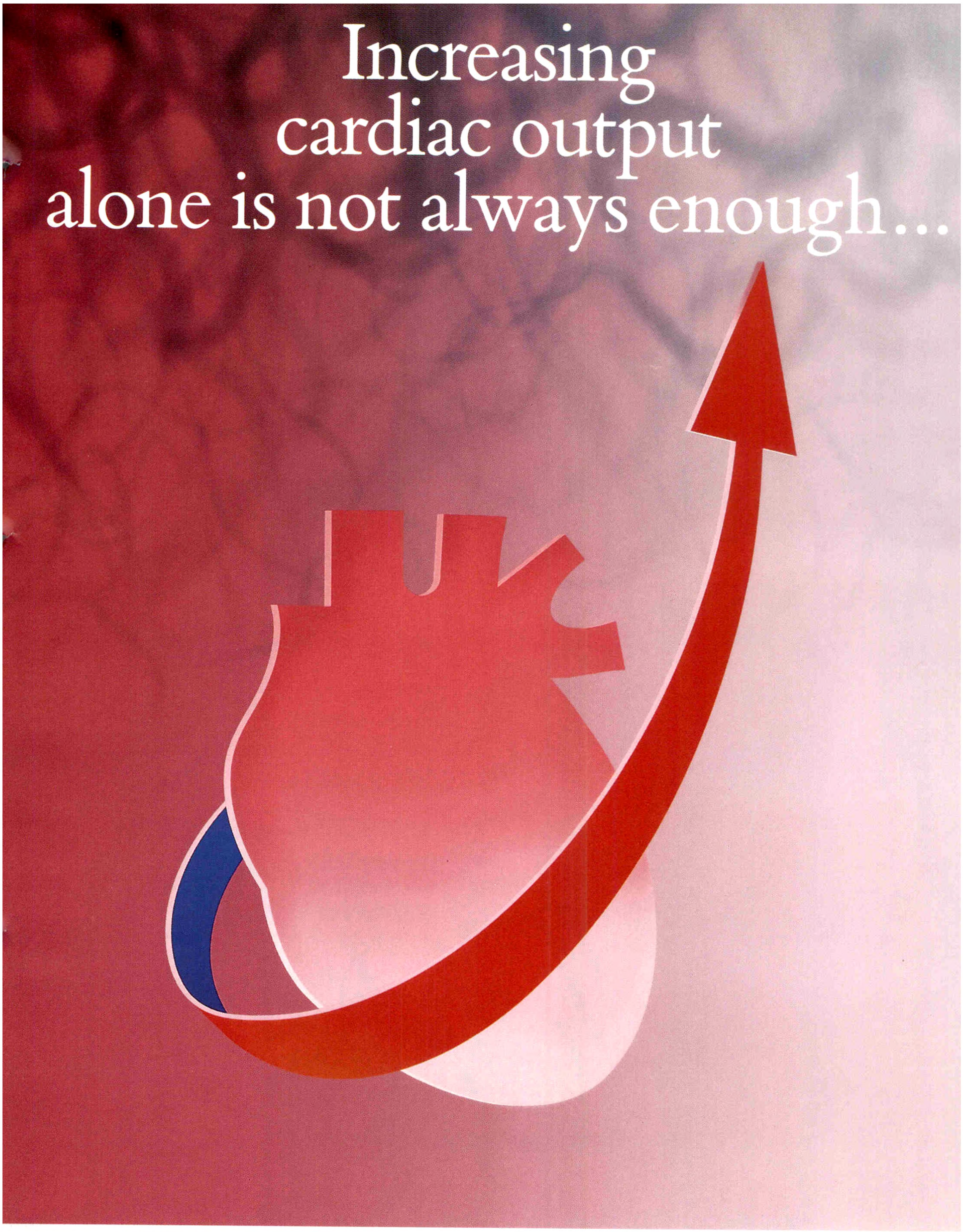

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3C-56C. 9. Leier C V. Am J Cardiol 1988; **62:** 86E-93E.

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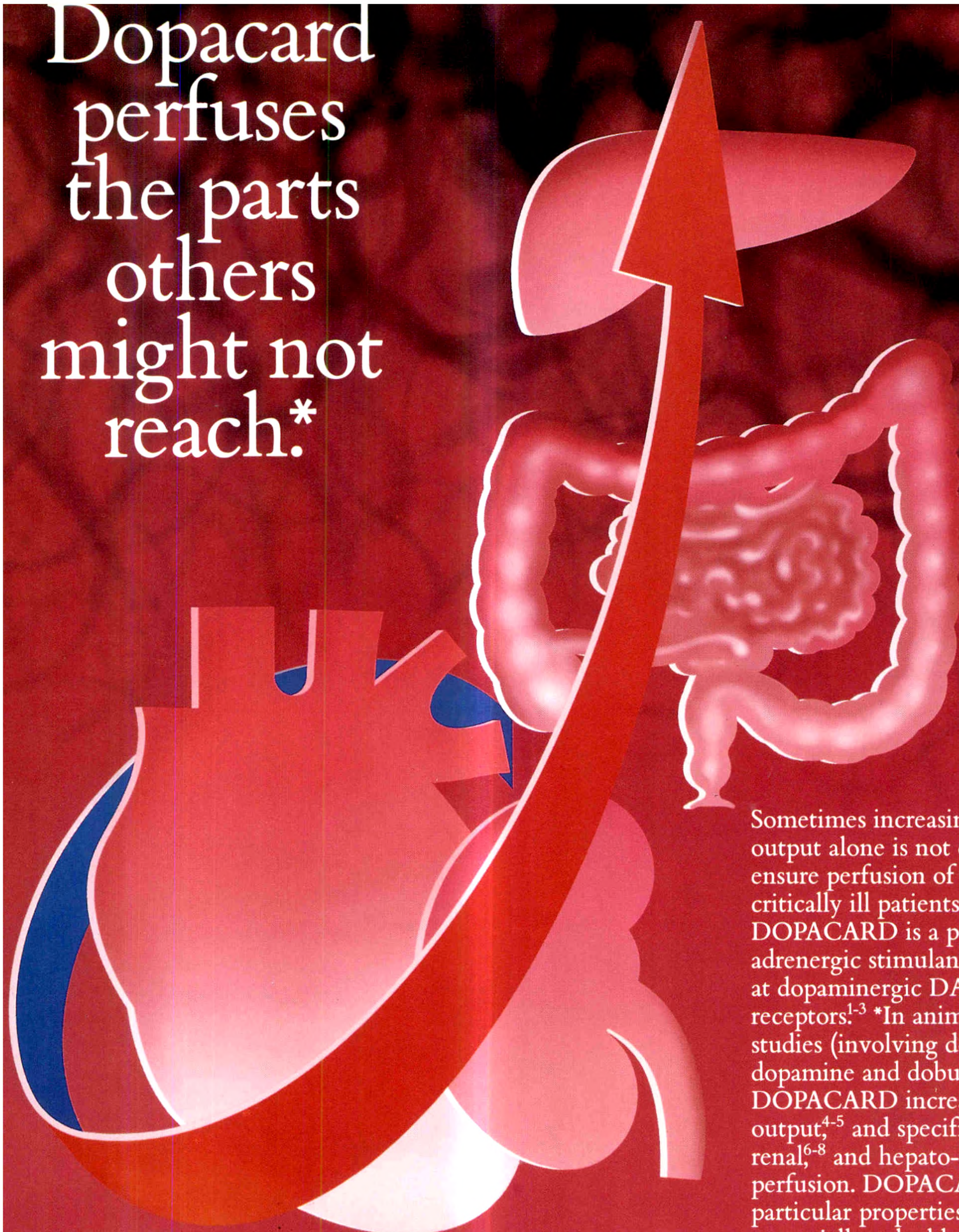
following: 0.9% Sodium Chloride Injection or 5% Dextrose Injection (500 or 250ml) **Recommended dosage for adults including the elderly:** Infusion should begin at a dose of 0.5μg/kg/min and may be increa
g/kg/min and then in increments (1μg/kg/min) up to 6μg/kg/min at 10-15 minute intervals. The rate of administration and duration of therapy should be adjusted according to the patient's response as determined l
blood pressure, urine output and, if possible, measurement of cardiac output. **Contraindications, Precautions, Warnings: Contraindications** Concurrent MAOI administration, left ventricular outlet obstructi
as hypertrophic obstructive cardiomyopathy or aortic stenosis), phaeochromocytoma, thrombocytopenia. **Precautions** If any correction of hypovolaemia is required this should be achieved before the administr
card. **Warnings** Dopacard should be administered with caution to patients with acute myocardial infarction or recent episodes of angina pectoris. A fall in circulating platelet numbers has been observed in some pati
lverse experiences attributable to alterations in platelet count have been seen in clinical studies. Plasma potassium may decrease and blood glucose may increase during Dopacard administration and care is required i
ients with, or at risk of, hypokalaemia or hyperglycaemia. There is no evidence to suggest that Dopacard has significant arrhythmogenic potential. However, if a cardiac arrhythmia occurs during administration a
tion or temporary discontinuation of the infusion should be considered. The safety and efficacy of Dopacard for use in children has not been established. **In patients with a marked reduced systemic vascular resi**
card should not be used as a direct substitute for pressor agents or other inotropes. Use in Pregnant and Lactating Women Dopacard is not currently recommended for use in pregnant and lactating wom
effects Increases in heart rate may occur during infusion of Dopacard; in most cases these are not clinically significant. Occasionally excessive tachycardia or ventricular ectopic beats have been noted during the i
sitating reduction or temporary discontinuation of the infusion. Tachycardia may be more pronounced in patients with pre-existing atrial fibrillation. The following side-effects have been reported infrequently,
at high dosage: nausea, vomiting, anginal pain and tremor. **Interactions** Dopacard may potentiate the effects of exogenous noradrenaline or dopamine. Concomitant use of B2 – adrenergic
opamine receptor antagonists may cause attenuation of the pharmacological effects of Dopacard. **Product Licence No:** PL 0113/0126 **Name and Address of Product Licence Holder:**

Dopacard perfuses the parts others might not reach.*



Sometimes increasing cardiac output alone is not enough to ensure perfusion of vital organs i critically ill patients. DOPACARD is a potent ß$_2$-adrenergic stimulant with activit at dopaminergic DA$_1$ and DA$_2$ receptors.[1-3] *In animal and clinica studies (involving dopexamine, dopamine and dobutamine) DOPACARD increased cardiac output,[4-5] and specifically improve renal,[6-8] and hepato-splanchnic[9] perfusion. DOPACARD's particular properties make it a potentially valuable agent in the management of critically ill patients in cardiac surgery where multi-organ failure can be a threa

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and in detailed written instructions presented with the kit, is that having obtained vascular access with the 18 gauge needle, the Arrow safety syringe is left attached to the needle and the guidewire passed down the central lumen of the syringe and needle; the syringe and needle are then removed as a unit. This technique has the potential to allow inadvertent arterial puncture to remain unrecognised until after the vessel has been dilated and the multilumen catheter introduced. Alternative techniques to aid recognition of inadvertent arterial cannulation include: (1) removal of the syringe from the needle to observe the flow and colour of the blood from the needle hub; (2) transduction of vascular pressure directly from the needle, which also requires removal of the syringe from the needle; (3) blood gas analysis of the aspirate.

There are other factors which I believe contribute to the loss of discriminatory sensitivity during venepuncture and passage of the guidewire. The syringe plunger moves with a hesitant and sticking movement within the barrel, due to resistance of the plunger on the metal central lumen of the syringe. No clear idea of the pressure within or of the force required to aspirate blood to the syringe is obtained. In passing down the central lumen of the syringe, the guidewire passes through a valve designed to prevent air leaking down the lumen into the patient and to prevent leakage of blood in the opposite direction. This valve presents a resistance to the passage of the guidewire with subsequent loss of feel for increased resistance due for example to misplacement of the wire.

For these reasons I consider that the Arrow safety syringe is a misnomer and recommend that it not be used routinely for detection of a vessel or for passage of the guide wire.

Launceston General Hospital,
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Australia
S. Fraser

A reply

Dr Fraser's points are well taken, but it is important to recognise that the Arrow Raulerson syringe offers the *optional* feature of allowing the guidewire to be passed directly through the syringe without disconnecting it from the needle. Prior to the invention of the Raulerson syringe by Dr Dan Raulerson, the syringe had to be disconnected from the introducer needle before advancing a guidewire through the needle into the vessel during attempted cannulation. Thus, three potential problems were addressed: (1) loss of vessel access may result during the process of disconnecting the syringe from the needle, since the needle tip tends to move; (2) the risk of air embolisation during spring-wire introduction is reduced, since the needle is not open to the atmosphere; (3) the blood is better contained.

The Arrow Raulerson syringe not only allows for the capability of passing a spring-wire guide, it does function as a standard, ordinary syringe. Thus, during vessel cannulation, the Raulerson syringe can be used to aspirate blood and then detached from the needle so the guidewire can be passed, as is traditional practice. Our current instructions indicate the importance of not relying on the colour of the blood as an accurate indicator of the vessel cannulated. In addition, each Raulerson syringe kit includes a transduction probe (20 G × 3.5 inch blunt needle) for insertion into the syringe plunger. The transduction probe interrupts the valves in the syringe plunger and allows the pressure from the vessel cannulated to be transduced without disconnecting the syringe from the needle. Pressure waveform transduction has been shown to be a reliable indicator of venous cannulation [1].

Finally, the loss of feel described by Dr Fraser is one of physician preference and perception. This is certainly not a universal statement and again, if desired, the Raulerson syringe can be detached from the needle and the guidewire inserted in the usual fashion. The advantages of the Raulerson syringe, coupled with the use of the transduction probe, offers many physicians an important enhancement to successful vessel cannulation.

Arrow International,
Reading, Pennsylvania 19610,
USA
P.J. McGregor

Reference

[1] Jobes DR, Scwartz AJ, Greenhow DE, Stephenson LW, Ellison N. Safer jugular vein cannulation recognition of arterial puncture and preferential use of the external jugular route. *Anesthesiology* October 1983; 353–5.

Supplementary oxygen causing surgical emphysema

Further to the editorial 'Supplementary oxygen — potential for disaster' (*Anaesthesia* 1991; **46:** 905–6) we report a problem we encountered recently following the use of supplementary oxygen.

A 12-year-old girl with Down's syndrome underwent posterior spinal fusion to correct her scoliosis; the operation and anaesthetic were uneventful. At operation a right subclavian central line was inserted. A postoperative chest X ray showed no pneumothorax. Postoperatively she was extremely restless despite adequate pain relief with an intravenous morphine infusion. She required oxygen therapy, without which her oxygen saturation fell to 84%. She was unable to tolerate oxygen via a facemask and we were unable to use nasal cannulae as she had a 12 FG nasogastric tube in her left nostril. It was decided to provide supplementary oxygen via a 6 FG suction catheter placed in her right nostril to a depth of 3 cm and secured at this distance by sticking the catheter to her cheek with adhesive tape. Oxygen was delivered at a flow of $0.5\,\mathrm{l.min^{-1}}$.

Recovery was uneventful until 60 h postoperatively when it was noted that she had developed marked swelling of the right side of her face and neck extending from just above the clavicle to above the orbit. On clinical examination this was found to be surgical emphysema. It was significant that she had removed her central line several hours earlier. An occlusive dressing had been placed over the exit site. No emphysema was seen below the right clavicle. Fortunately at no time was her airway compromised.

It was suspected that oxygen via the nasal catheter might have been the cause of the surgical emphysema. The catheter was therefore removed, but with some difficulty, as it seemed adherent to the nasal mucosa. A chest X ray was repeated and again showed no pneumothorax. The surgical emphysema gradually reduced over the following 3 days, but was noted to fluctuate with nose blowing.

We presume that a small mucosal tear occurred either with insertion or movement of the nasal catheter and that continual oxygen flow caused the surgical emphysema. Surgical emphysema of this origin could well compromise the airway and is another potentially serious complication of oxygen therapy delivered by this route.

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P. Radford
B.J. Eppel

The effectiveness of premedication

Although the aims of premedication may be disputed, whether they be anxiolytic, amnesic, sedative or 'narcotic', or indeed whether premedication is necessary at all, a large body of clinical opinion recognises a 'well-premedicated' patient. The possibility of repeated anaesthesia really necessitates that the 'effectiveness' of premedication be recorded objectively. The following scoring system has been elaborated over the years and has been found to be most useful: 0, no effect; 1, subjective effect only; 2, subjective and objective effect but awake; 3, sleeping but responds to *normal* conversation; 4, not responsive to normal conversation.

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J.M. Leigh

Subcutaneous opioids: the painless approach

Dr Teillol-Foo's observations on the use of an indwelling intramuscular cannula for postoperative analgesia (*Anaesthesia* 1991; **46:** 897) are interesting and should certainly be considered before committing patients to repeated intramuscular injections. If one of the aims of the anaesthetist is to relieve pain, we should not accept that the barbaric infliction of a 20 gauge needle (or 21 gauge as we would use) is justified by its end result.

In central Nottinghamshire we have recently introduced an acute pain service and, as in many other centres, we make wide use of patient controlled analgesia, but as we have a paucity of equipment we run a *subcutaneous* regimen alongside. This involves an indwelling cannula, usually a 20 gauge Venflon, which is sited subcutaneously during anaesthesia, either on the chest wall or the anterior thigh (especially if a regional block has been used). Nurses are requested to give a variable dose of opioid (usually morphine) according to a rigid protocol. The success of this method depends upon the enthusiasm of the nurses, who willingly assess patients' pain hourly and give appropriate quantities of drug, despite some difficulties with the Controlled Drug Register. Motivation is enhanced by their observing a great improvement in postoperative pain relief. All risk of needle-stick injury at the patient site is avoided as the injection is given via the Venflon port; the small 'dead-space' is usually only relevant at the first administration and, as this dose is usually the largest, say 1 ml, this should not be significant. Nurses are instructed not to dilute drugs not to flush the cannulae.

It has been shown that absorption from both subcutaneous and intramuscular sites follows a similar time course and that the absorption profile in a particular patient is more reproducible via the same subcutaneous site than via several different intramuscular ones. The actual injection may not be entirely painless and some patients do describe a mild irritation at the cannula tip, although all questioned would agree that the regimen is far superior to the intramuscular method. Unfortunately, we have not found that the regimen produces any significant reduction in nausea and vomiting and, as antiemetics cause a local skin reaction when given subcutaneously, such injections cannot be combined with the opioid, except perhaps when using low dose droperidol.

It may, of course, be necessary to administer an occasional bolus dose of opioid to a patient who does not have an indwelling cannula. We believe that such injections could also be prescribed subcutaneously and, therefore, we can see no further role for intramuscular opioids, unless they are to be combined with an antiemetic.

We freely admit that we are not the first to advocate subcutaneous injections of opioids and perhaps not the first to suggest the use of an indwelling cannula, but, from our recent experience we would confidently recommend this technique be used more widely, even by our more sceptical immediate colleagues. Comparison of this regimen with that of Dr Teillol-Foo would be worthwhile.

Mansfield Hospitals,
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P.T. Bull
M.J. Mowbray
S.J. Markham

Burns due to pulse oximetry

A 4-month-old baby, whose lungs were ventilated for 14 days for ventilatory failure secondary to bronchiolitis, suffered burns to his big toe related to the site of application of a pulse oximeter probe (Fig. 1). The probe involved was a Nellcor N25 oxisensor and was combined with a Hewlett Packard HP Model 66S monitor and module. Prior to the discovery of the burn, the patient had no periods of poor peripheral perfusion and there had been no problems with the pulse oximeter trace. On the 13th day he was noted to have blistering beneath the pulse oximeter probe on two-thirds of the circumference of his left big toe, and a similar but smaller lesion on the right big toe. These had not been present during examination earlier in the day and had not been noticed during routine rotation of the position of the probe. This consists of movement of the probe to another limb every 3 h and is standard practice for the nurses on the intensive care unit. The pulse oximeter probe was removed and the light source felt to be hotter than usual. The lesions have been managed conservatively and are resolving satisfactorily. The pulse oximeter probe was returned to the manufacturer for assessment.

Following this episode, the heat production from a number of similar probes was tested. Six pulse oximeter probes were suspended in a Drager 8000 incubator main-

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The seminar is timed so that it will be possible for members to register for the two-day symposium, 'The law and the anaesthetist', to be held at the College of Anaesthetists in London on 5–6 November 1992.

The Directors of Studies will be **Dr John S M Zorab**, Department of Anaesthesia, Frenchay Hospital, Bristol, and **Professor Cedric Prys-Roberts**, Sir Humphry Davy Department of Anaesthetics, Bristol Royal Infirmary, Bristol.

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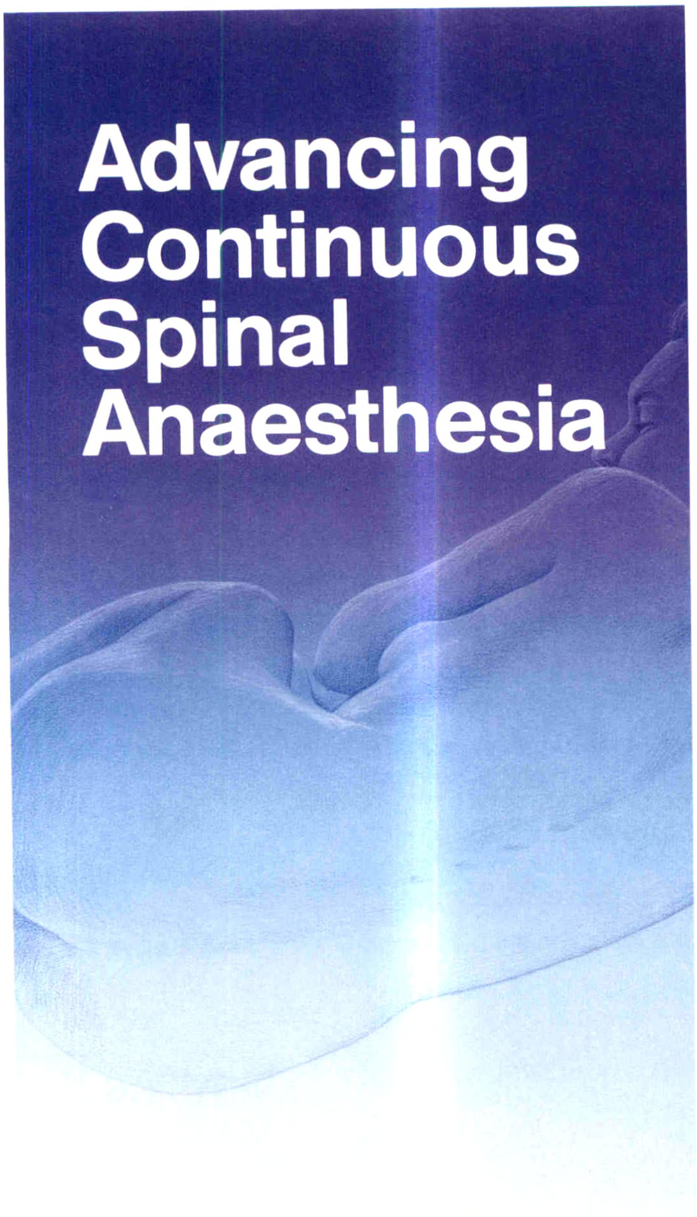

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circulation in anaesthesia. Oxford: Blackwell Scientific Publications, 1980: 179.

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[7] Kortly K, Ebert TJ, Vucins EJ, Roerig DL, Kampine JP. Baroreceptor reflex control of heart rate during morphine sulfate, diazepam, N_2O/O_2 anesthesia in humans. *Anesthesiology* 1984; **61:** 558–63.

A reply

Thank you for the opportunity to reply.

We are grateful to Dr Fassoulaki for drawing attention to his paper [1]. Reference to this work did not appear on databases until after we had submitted our manuscript to *Anaesthesia*, otherwise we would certainly have acknowledged it. The earlier paper he referred to [2] contained no information on the cardiovascular effects of nasal intubation.

Dr Fassoulaki makes some salient criticisms of our use of Student's *t*-test in the statistical analysis. He is particularly concerned about the possibility of false-positive errors. We therefore present between-group comparisons of our data using two-way analysis of variance: there were no significant differences between the two groups before intubation; during the 5 min postintubation period, arterial pressures were significantly greater in the nasal group (systolic: $p < 5E^{-8}$, mean: $p < 5E^{-6}$, diastolic: $p < 0.005$) and heart rates were significantly lower in the nasal group ($p < 0.05$). The question therefore must arise, why were our results so different from those of Dr Fassoulaki? He investigated 24 patients in whom anaesthesia was induced with midazolam, thiopentone and alcuronium. Their lungs were then ventilated for 10 min with oxygen 35% in nitrogen. We investigated 60 patients who received temazepam premedication and thiopentone and atracurium induction. Anaesthesia was maintained with oxygen, nitrous oxide and isoflurane. Individual anaesthetists must decide for themselves which technique most closely parallels their usual clinical practice.

Although Dr Fassoulaki reports that the systolic blood pressure (SBP) changes in his nasal intubation group did not differ significantly from the control group, it is interesting to note that in the discussion he states that the maximum increase in SBP in the nasal group was twice as high as in the oral group. He also found that oxygen consumption and carbon dioxide production were significantly greater after nasal intubation and he concluded that nasal intubation may be a more stressful procedure than oral intubation. This appears inconsistent with his finding of similar pressor responses in the two groups.

The heart rate data for Dr Fassoulaki's trial are recorded in Table 1 and Figure 2 of his paper. Unfortunately, the mean 'nasal' heart rates in the Table bear little resemblance to those represented in the Figure. Assuming that the Table contains the correct information, it can be seen that the mean heart rates in the nasal group were lower than those in the oral group during the first 3 postintubation minutes. In fact, the mean nasal heart rate was 17 beats.min^{-1} lower than the oral during the first postintubation minute, whereas the greatest difference in mean heart rates observed in our investigation was 8 beats.min^{-1}.

We made no assumptions about the mechanisms responsible for our heart rate observations, but did discuss briefly two possible explanations. Baroreceptor reflexes are depressed by anaesthesia, but they are not completely obtunded. Perusal of the papers cited by Dr Fassoulaki will indicate that the phenylephrine 'pressor test' still produces reflex slowing of the heart rate in anaesthetised patients, albeit at a reduced sensitivity level. Additionally, isoflurane has been shown to preserve baroreceptor function better than other commonly used inhalational agents [3]. Therefore, we believe that the possibility that baroreceptor reflexes contributed to the slower heart seen after our nasal intubations cannot be excluded at this stage.

Our paper aimed to assess the cardiovascular effects of nasal intubation under clinically appropriate anaesthesia. Because of the limitations of indirect arterial pressure measurement, we chose to investigate a large number of patients and used pulse oximetry rather than oscillometry to measure heart rate changes. We demonstrated particularly that the pressor response to nasal intubation clearly exceeds that of oral intubation. We believe that this information will be of interest and importance to anaesthetists, even though our findings conflict with those of a previous study.

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J.E. Smith
M.S. Grewal

References

[1] Fassoulaki A, Andreopoulou K, Saleh M, Kitharitzi D. Metabolic and cardiovascular responses following oral and nasal intubation of the trachea. *Acta Anaesthesiologica Belgica* 1990; **41:** 281–6.

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[3] Kotrly KJ, Ebert TJ, Vucins E, Igler FO, Barney JA, Kampine JP. Baroreceptor reflex control of heart rate during isoflurane anesthesia in humans. *Anesthesiology* 1984; **60:** 173–9.

Unblocking tracheal tubes

Tracheal tubes left *in situ* for long periods often become blocked [1]. The usual management of this problem is to change the tube, but this is not always easily possible. We describe a technique we used recently for unblocking a tracheal tube.

A 56-year-old man, weighing 105 kg had been admitted to the intensive care unit of another hospital 17 days previously where his trachea had been intubated and his lungs ventilated; a diagnosis of thrombotic superior vena cava (SVC) obstruction had meen made. Upper body swelling, culminating in stridor due to laryngeal and glottal oedema had caused respiratory obstruction and hypoxaemia and resulted in near cardiorespiratory arrest prior to tracheal intubation. Persisting SVC obstruction caused relentlessly progressive upper body and glottal oedema and he was therefore judged to be a very difficult re-intubation. Elective tracheostomy had been planned.

Late in the night prior to the tracheostomy, the ventilatory inflation pressures rose acutely and it proved impossible to pass a suction catheter down the lumen of the tracheal tube; his oxygenation remained adequate. Rather than attempt to change the tracheal tube it was decided to use a flexible fibreoptic bronchoscope to confirm our suspicion of a blocked tube, and to remove the blockage using suction under direct vision. Although a large plug of tenacious sputum was seen at the end of the tracheal tube and in the trachea, we were unable to remove it with the bronchoscope. Following pre-oxygenation, a size 10 Foley catheter was passed down the tube and 1.5 ml saline used to inflate the balloon. This was then withdrawn together with a sizeable mucous plug (Fig. 1). The patient remained well oxygenated throughout the procedure, and no further episodes suggesting tracheal tube blockage occurred prior to his uneventful tracheostomy the next day.

We feel that this may be a useful technique for removing sputum from tracheal tubes, when conventional techniques have failed.

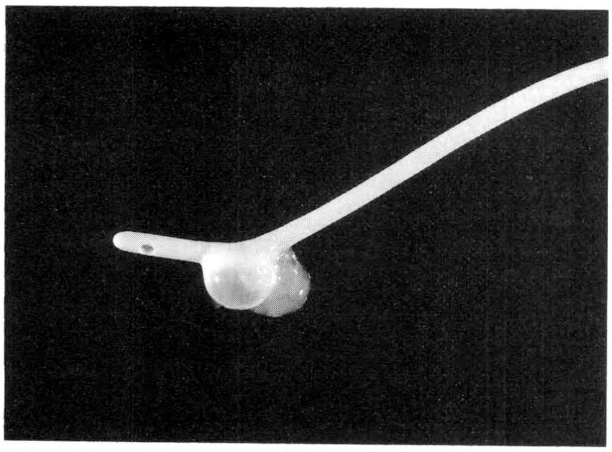

Fig. 1.

Southampton General Hospital,
Southampton SO9 4XY
J. Sizer
J.M.T Pierce

Reference

[1] Atkinson RS, Rushman GB, Lee JA, Comps J. *A synopsis of anaesthesia* (10th edn). IOP Publishing Ltd 1987.

Disablement of a ventilator disconnect alarm by a heat and moisture exchanger

It is common practice to add a heat and moisture exchanger (HME) to the tracheal tube to provide humidification and retain heat during anaesthesia for prolonged surgery. Recently I anaesthetised a patient who was having an oesophageal defect repaired and added an HME (Engstrom Edith) to the ventilatory circuit. A pressure-sensitive ventilator disconnect alarm (Medishield) and an end-tidal CO_2 monitor were used and intermittent positive pressure ventilation was provided by a Manley Pulmovent ventilator.

Approximately 4 h into the operation the surgeon informed me that he would be removing the tracheal tube from the laryngectomy stoma to suture around the site. During this procedure the capnograph duly alarmed, but the ventilator alarm had failed to activate. On examination, it was noted that the ventilator was cycling with a peak airway pressure of 1.0 kPa and that the disconnection alarm was also cycling. Adjustment of the low pressure alarm limit failed to activate the alarm and further checks of the patient breathing system revealed that removing the HME re-activated the alarm. Replacement with a fresh HME restored the function of the disconnect alarm and indeed the peak airway pressure of the ventilator when disconnected was now recorded at 0.2 kPa.

This disturbing event indicates that the build-up of moisture in this particular HME disabled the ventilator disconnect alarm during the course of a prolonged procedure and that a potentially fatal ventilator disconnection could have remained undetected in this patient without the aid of the capnograph. This problem has been described, but was not thought to be a problem with this particular HME, even when wet [1]. It must be emphasised therefore that the use of this equipment must include a capnograph in the system to monitor any possible disconnections, because the ventilator disconnect alarm may become disabled during the course of a prolonged procedure.

Royal Victoria Infirmary,
Newcastle-upon-Tyne NE1 4LP
K.A. Milligan

Reference

[1] Pryn SJ, Crosse MM. Ventilator disconnexion alarm failures. The role of ventilator and breathing accessories. *Anaesthesia* 1989: **44;** 978–81.

Problems with continuous EEG monitoring

In a recent paper (*Anaesthesia* 1991; **46:** 750–5) about continuous cerebral function monitoring, Dr Shearer and colleagues reported a loss of 19% of their data because of drying of the conductive jelly. The jelly was used to produce a low impedance between the skin and silver/silver chloride electrodes held in place with collodion. We encountered a similar problem with continuous EEG recording. The problem can be overcome by covering all the scalp electrodes with a head bandage and covering electrodes applied to hairless skin with a small piece of waterproof dressing (sleek). If the bandage evenly covers all of the scalp and is left undisturbed, it will reduce drying of electrodes and maintain a low impedance for up to 48 h. We found the best system was to remove the bandage, scarify the electrodes and rebandage the head every 24 to 36 h. The bandage also had the added advantage in that the electrodes were less likely to be inadvertently pulled off.

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Propranolol overdose

I read FK Mcvey's and CF Corke's case report on propranolol overdose with interest (*Anaesthesia* 1991; **46:** 744–6). It seems to be a more common problem than it was 7 or 8 years ago. I would like to point out a few important observations made 2 years ago in a similar case. Glucagon remains the principal drug under these circumstances but in our patient we did not limit the dose of glucagon, as has been suggested [1]. The bolus dose and infusion rate were increased until we got an appropriate response, namely a systolic arterial pressure above 80 mmHg. We ended up giving our (50 kg) patient a 15 mg bolus and an infusion of 12–15 $mg.h^{-1}$. We also faced a problem with inadequate glucagon supply. In the entire hospital we were able to locate only 17 mg of glucagon. With the help of police and the Pharmacy Department, we were able to open a warehouse at 0200 h and obtain another 120 mg (10 mg multidose vials), which was sufficient to get us through the most crucial period.

Isoprenaline remains the pharmacological antidote for propranolol overdose. One has to remember that the log dose response curve of isoprenaline in the presence of propranolol is moved to the right. Therefore, these patients do not require a maximum infusion rate of isoprenaline of 20 $\mu g.min^{-1}$. The dose required to produce the desired effect can be 10 times this amount [2]. Our patient was receiving an isoprenaline infusion at rate of 100–150 $\mu g.min^{-1}$ at the time when the supply of glucagon ran out. Luckily, the patient survived.

Royal Berkshire Hospital,
Reading RG1 5AN
R.B. Vadhera

References

[1] Weinstein RS. Recognition and management of poisoning with beta-adrenergic blocking agents. *Annals of Emergency Medicine* 1984; **13:** 1123–31.

[2] Agura ED, Wexler LF, Witzburg RA. Massive propranolol overdose. Successful treatment with high dose isoproterenol and glucagon. *American Journal of Medicine* 1986; **80:** 755–7.

Hysteria

I was fascinated by Adams and Goroszeniuk's description of their dental patient's hysterical reaction to general anaesthesia (*Anaesthesia* 1991; **46:** 932–4).

Many years ago I gave a healthy woman in her 20s only a single intravenous dose of methohexitone for the removal of one tooth in the dental chair. The whole procedure was straightforward but she would not wake up. About 20 min later I went to the waiting room to speak to her mother who told me that this was to have been her daughter's wedding day, but the ceremony had been cancelled by her fiancé. I thought then that this was a case of hysteria. She responded to a brisk stimulus and, on command, woke up.

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A.L. Forrest

A wee problem in the dental surgery

I wish to relate a recent experience which may be of interest to others. During a recent anaesthetic session in a dental surgery, I anaesthetised a child in an electrically operated dental chair, in the horizontal position. Immediately after induction of anaesthesia, the chair, apparently spontaneously, resumed the upright position and refused to respond further to its controls. The anaesthetic and extraction were, fortunately, completed successfully, and it then became apparent that the child had had a full bladder which had emptied on loss of consciousness and 'shorted' the chair electrics.

After replacing burnt-out parts at some expense, my dental colleagues have now waterproofed the vital regions of the chair, and I hope that the telling of this tale will encourage others, like myself, to check patients' pre-operative fluid balance more carefully in future.

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W. McCaughey

Early textbooks on anaesthesia

In recent years, knowledge of the early writings on surgical anaesthesia has been enriched thanks to articles by Prof. Secher (*Anaesthesia* 1985; **40:** 385–6 and 1987; **42:** 1022) and others (*Anaesthesia* 1985; **40:** 386 and 1988; **43:** 807–8). In this letter we would like to extend the list of books published in 1847.

(1) The 4th and 5th editions of Morton's *Letheon* were published in Boston in the months of January and May 1847 respectively [1, 2].

(2) Morton's *On the loss of teeth, and the way of restoring them, as practised by W.T. Morton and Francis Whitman* should be included among early books on anaesthesia because its Appendix on ether (entitled 'Great Discovery') is at least as long and as historically interesting as some of the texts that already figure in the list [3].

(3) A Spanish translation of Burgieres' book (first published in Brussels in 1847) was published (likewise in 1847), under the title *Estudios estadísticos y críticos sobre la eterización*, by the Cádiz surgeon Antonio Gracia Alvarez. The translator furthermore supplemented the original text with an account of experiments by Spanish surgeons [4].

(4) A book on ether anaesthesia that provides an interesting account of the history of anaesthesia during its first year, and which is not mentioned in the lists referred to above, is Aloys Martin's *Geschichte der Entdeckung und Ausbreitung des Aetherismus*, published in Munich in 1847 [5].

(5) Another book that appears to have gone unnoticed is the *Breve tratado sobre la eterización* published by Dr Juan Vicente Hedo of Valencia, one of the first Spanish surgeons to use ether in humans and one of the first in the world to carry out trials with rectally administered ether [6].

Hospital General de Galicia,
E 15705 Santiago de Compostela,
Spain
A. Franco
J. Cortés
M.I. Vidal
J. Alvarez

References

[1] Morton WT. *Letheon*, 4th edn. Boston, 1847: 24.

[2] Morton WT. *Letheon*, 5th edn. Boston, 1847: 88.

[3] Morton WT. *On the loss of teeth, and the modern way of*

restoring them, as practised by W.T.G. Morton and Francis Whitman. pp. 33. and appendix 'Great Discovery'. pp. 6. Boston, 1847.

[4] Burguiéres M. *Estudios estadísticos y críticos sobre la eterización*. A Spanish translation by Alvarez Gracia. Cádiz (Spain), 1847: pp. 65.

[5] Martin A. *Geschichte der Entdeckung und Ausbreitung des Aetherismus*. München, 1847: pp. 39.

[6] Vicente Hedo J. *Breve tratado sobre la eterización, con varias observaciones y experimentos en los animales*. Valencia (Spain), 1847.

Anaesthesia, 1992, Volume 47, pages 282–283

Index of computer programs

Since the index of computer programs was first published, there have been considerable changes in the style of computing and the index is no longer appropriate. The programs listed below will be the last to be published in the journal. Anaesthetists interested in computing and the development of specialist programs for anaesthesia are advised to contact the Society for Computing and Technology in Anaesthesia (SCATA). The address can be found in most issues of *Anaesthesia News.*

Author J. M. Slade, Senior Registrar, Department of Anaesthetics, University Hospital of Wales, Heath Park, Cardiff CF4 4XW.

Title Cardiff Respiratory Measurement Software (CRMS).

Description (1) Data collection. Data from pulse oximeter, Densa body wall monitor, capnograph and PCA pump are processed into compact code and written to floppy disc (100 kbytes.24 h^{-1} collection). A detailed record of each apnoeic event may also be written to disc as it is logged, for examination afterwards. Oxygen may be administered to the patient by solenoid valve operated by an analogue output in response to low arterial saturation. (2) Data retrieval. The fraction of time spent below a given arterial saturation in each 4 h period is calculated. Saturation may be summarised graphically as a nest of frequency distribution histograms. There is the facility to calculate the total number of central and obstructive apnoeas, subdivided by length, in each 4 h period. The times of central and obstructive apnoeas and logged PCA doses are available. The trend of respiratory rate, estimate of variability of respiratory rate and incidence of desaturation episodes can be presented graphically.

Language LabVIEW 2.0.6.

Computing facility Macintosh II with NB-M10-16-H input/output board.

Availability 3.5 inch discs and operating manual from B. Williams, Department of Anaesthetics, University Hospital of Wales, Heath Park, Cardiff CF4 4XW.

Author C. N. Barthram, Department of Anaesthesia, Ninewells Hospital, Dundee DD1 9SY.

Title CALMIC (a dosage calculator for Gentamicin and Netilmicin).

Description CALMIC provides three means of calculating individual patient doses of Gentamicin and Netilmicin given as i.v. boluses. (1) Calculation of loading dose and subsequent doses, based on patient age, sex, weight, serum creatinine. Also estimates GFR. (2) Calculation of dose from two serum levels of aminoglycoside. The program aims for a 1 h peak level of 9 mg.l^{-1} and a trough of 1.5 mg.l. Useful in ICU where fluid compartments and renal function may be changing daily. (3) Calculation of dose from one serum level of aminoglycoside. Similar to above though less accurate.

Language MicroSoft Quick Basic 4.5 (under MS-DOS 2.1 or higher). The Basic program is compiled, and runs under MS-DOS.

Computing facility IBM-PC compatible.

Availability 5.25 inch or 3.5 inch discs, from the author.

Author G. L. Hutchison, Consultant Anaesthetist, Department of Anaesthesia, Ninewells Hospital and Medical School, Dundee DD1 9SY.

Title REFSAID Reference Processor.

Description The program is a small reference database, capable of handling up to 100 references, to aid the preparation of articles for publication. References are automatically numbered, then can be edited, moved, deleted, sorted or saved onto disk as an ASCII file. New references can be appended or inserted at any time, and files held on disc can be merged together. Data entry is aided by the automatic generation of as much of the reference format as possible. The program recognises the names of over 100 journals, selected from a menu or entered in the form of short (five letter or less) abbreviations. The user may choose the style of reference and page numbering (Harvard or Index Medicus), author names (capitals, lower case, *et al.* thresholds) and journal names (full, abbreviated) required by the journal to which the article is to be submitted.

Language Microsoft QuickBASIC 4.5 (Compiled into a stand-alone file which requires only MS DOS to run).

Computing facility Any IBM PC compatible running MS-DOS 2.1 or higher. Any monitor, 5.25 inch or 3.5 inch disc.

Availability Free from the author. Send formatted disc and disc mailer.

Author G. L. Hutchison, Department of Anaesthesia, Ninewells Hospital, Dundee DD1 9SY.

Title TRIALAID Clinical Trial Utilities.

Description The program is intended as a tool for the setting up of clinical trials.

Input: Simple details of the data you anticipate analysing at the end of the study. For quantitative data, an estimate of study and control group means and standard deviation is required. For qualitative data, the program will request the percentage of subjects in each group you anticipate being affected by the outcome of interest.

Output: A table of possible sample sizes.

The program displays a variety of sample sizes, arranged according to the level of statistical significance and the study power required. Once the sample size is decided, the program will randomise subjects to the groups required. The results of the randomisation can be output to screen, printer or disk file.

Language Microsoft QuickBASIC 4.5. (Complied into a stand-alone file which requires only MS DOS to run.)

Computing facility Any IBM PC compatible, running MS DOS 2.1 or higher. Any monitor type, 5.25 inch 360K or 3.5 inch 720K disk.

Availability Free from the author. Send a blank disk and a disk mailer.

Authors IBM version: G. L. Hutchison; BBC B version adapted by A. J. Shearer, Department of Anaesthesia, Ninewells Hospital, Dundee.

Title INSULAID, an intensive care insulin infusion calculator.

Description INSULAID is an insulin infusion regimen for use in adults receiving continuous carbohydrate infusion in the intensive care unit. It accepts details of the current insulin infusion rate and the present and previous blood glucose concentrations (as measured by reagent strip), and calculates a suitable new rate of insulin infusion. The program includes full instructions on how to start and maintain the regimen, together with individual help screens for particular topics. A reference to the original publication containing the equations used is also included. The program is based on the Ninewells Hospital insulin-dosage slide-rule, (© 1986, A. J. Shearer).

Languages Microsoft QuickBASIC 4.5. (Compiled into a stand-alone file which requires only MS DOS to run.) BBC Basic.

Computing facility Any IBM PC compatible, running MS DOS 2.1 or higher. Any monitor type, 5.25 inch 360K or 3.5 inch 720K disk. BBC B, 5.25 inch disk.

Availability Both the program and the insulin-dosage slide-rule are available, at £5 each, from Dr A. J. Shearer, Consultant in Anaesthetics and Intensive Care, Department of Anaesthetics, Ninewells Hospital and Medical School, Dundee DD1 9SY.

Anaesthesia, 1992, Volume 47, page 283

Hazard notice

Graesby Medical Ltd, PCAS syringe pump: risk of overinfusion HC(Hazard)(91)40.

Following the issue of SAB(90)85, a further overinfusion incident has occurred with a patient controlled analgesia (PCAS) syringe pump. The cause of the overinfusion has not yet been satisfactorily explained and users should remove them from use or monitor them closely. These pumps have been temporarily removed from sale.

Anaesthesia, 1992, Volume 47, page 284

Errata

Anaesthesia, 1991, Volume 46, pages 521–522

Editorial—The pill, HRT and postoperative thromboembolism: cause for concern?

E.M. Whitehead and M.I. Whitehead

Reference 4 was misquoted in the above editorial. The correct reference should be:

Hutchison GL. Oral contraception and postoperative thromboembolism: an epidemiological review. *Scottish Medical Journal* 1989; **34:** 547–9.

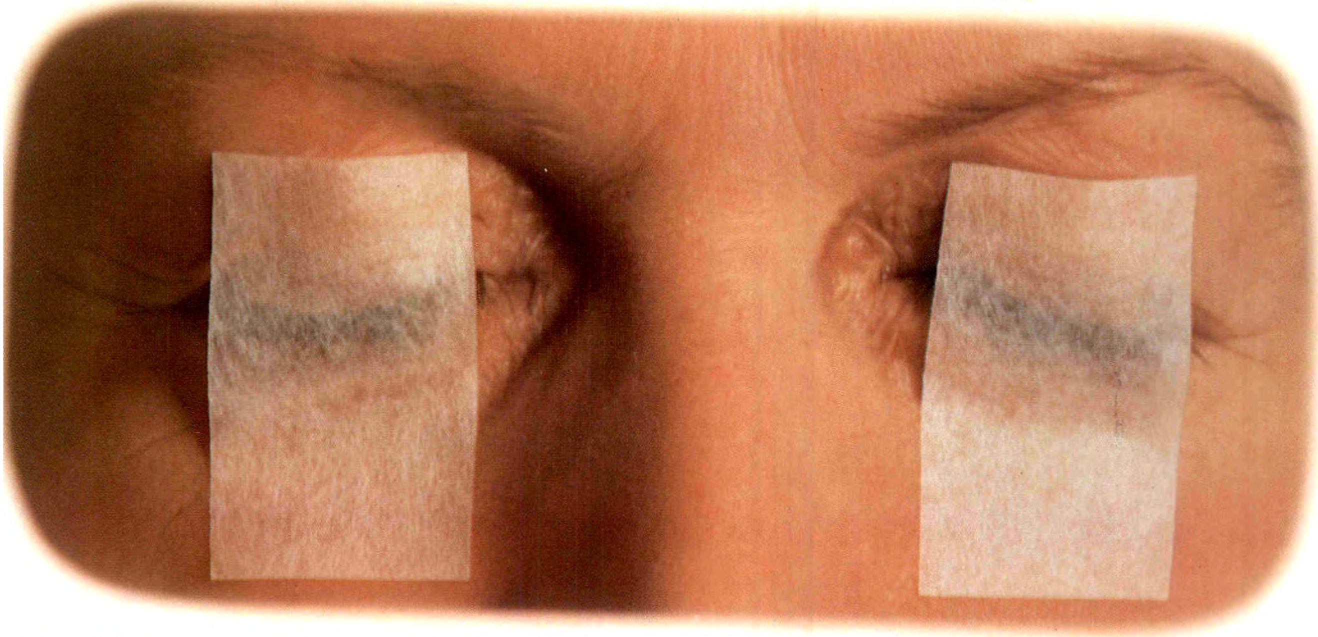
Anaesthesia, 1989, Volume 44, page 865

The use of the fibreoptic laryngoscope to confirm the position of the laryngeal mask

J. Payne and J. Edwards

We omitted to publish J. Edwards' name as one of the authors of the above letter.

HOW CAN A HIP OPERATION AFFECT THE EYE?



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References: 1. Cross, D.A. *et al., Anesthesia and Analgesia . . .*

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Anaesthesia

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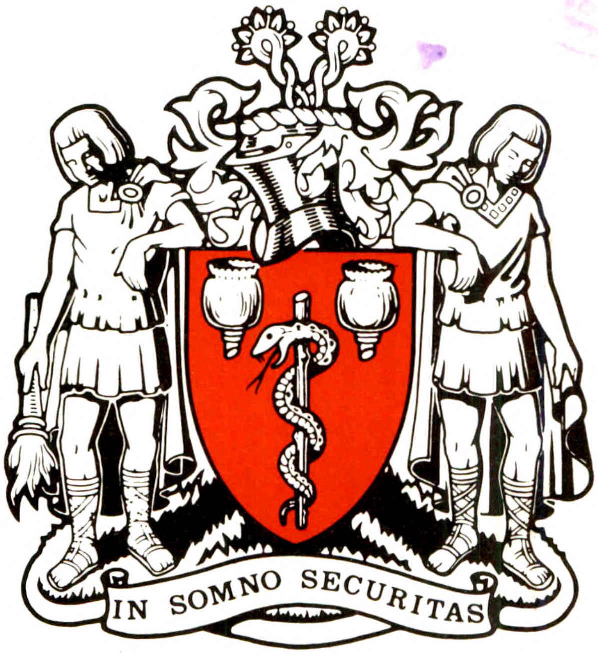

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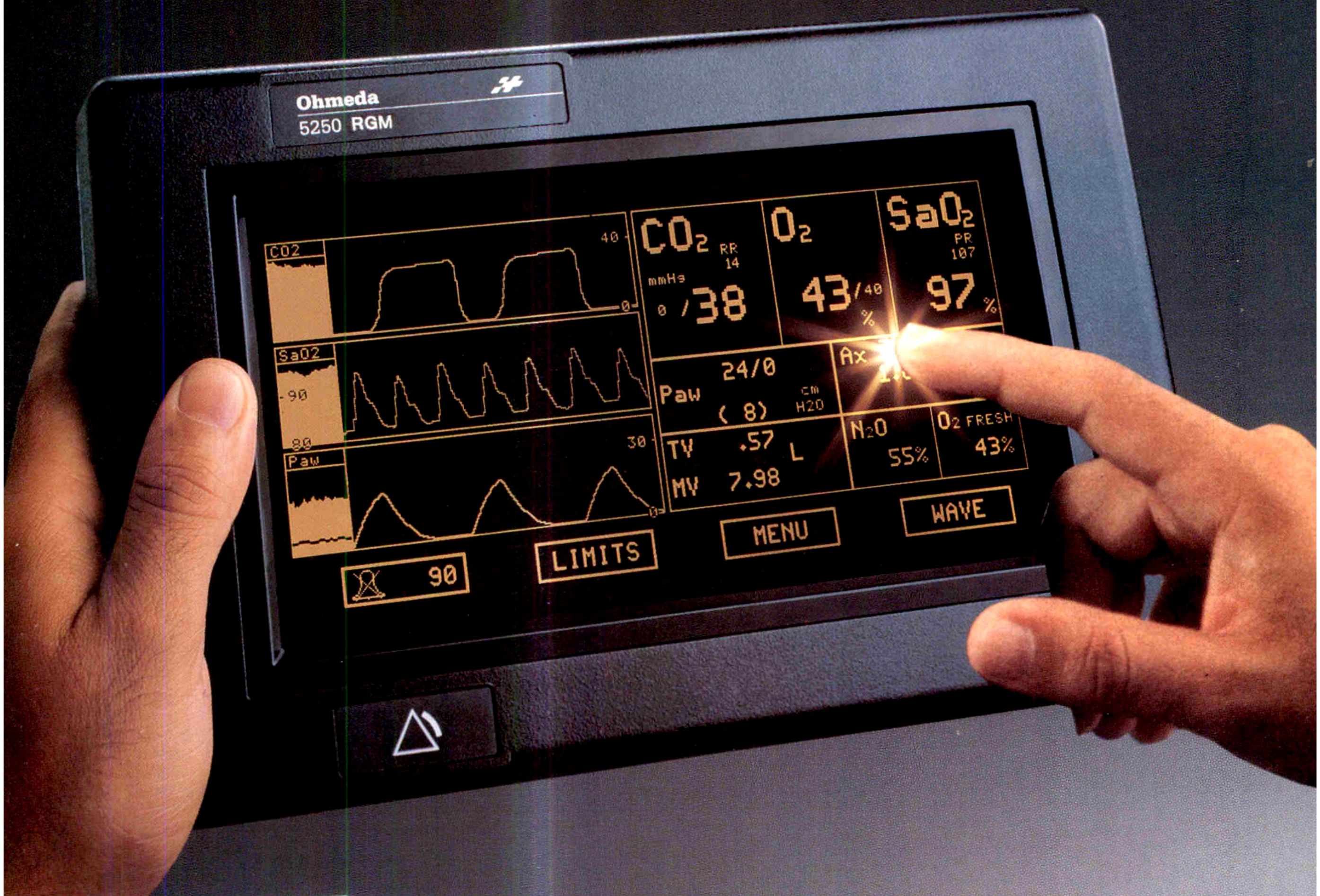

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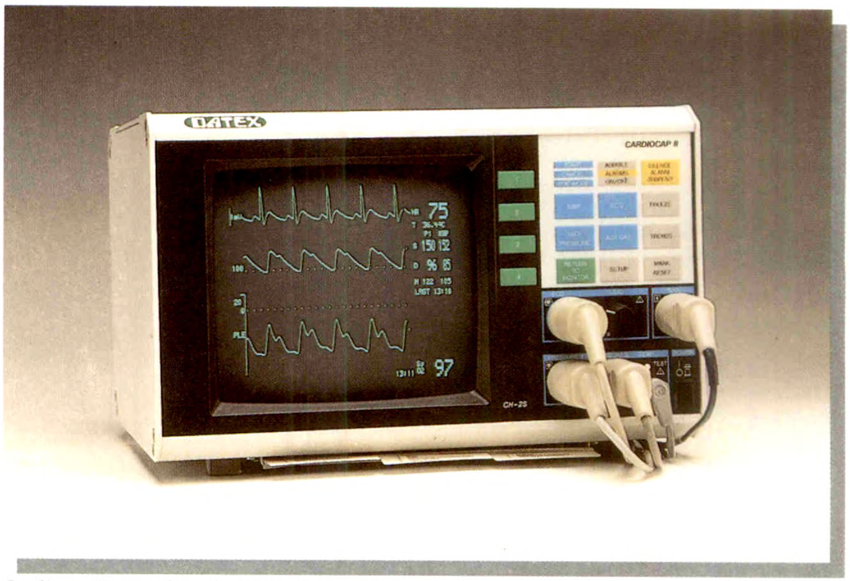

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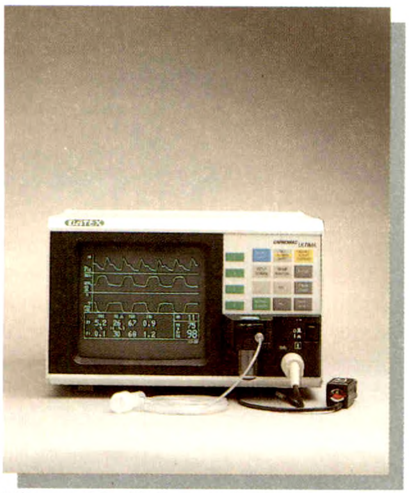

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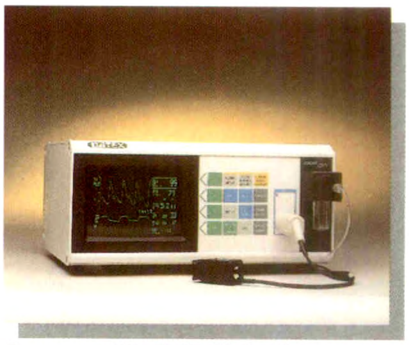

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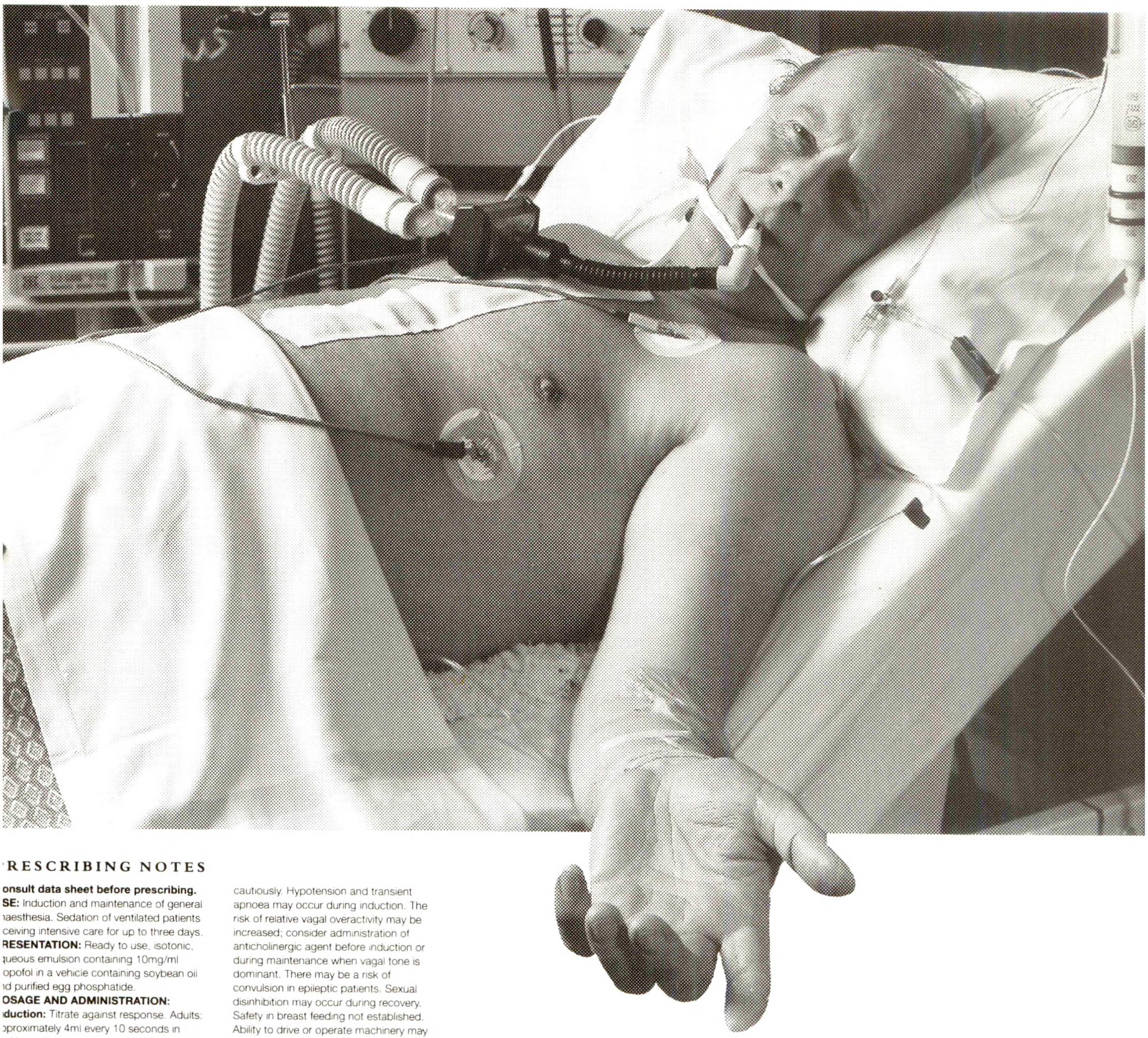

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ars: not recommended.
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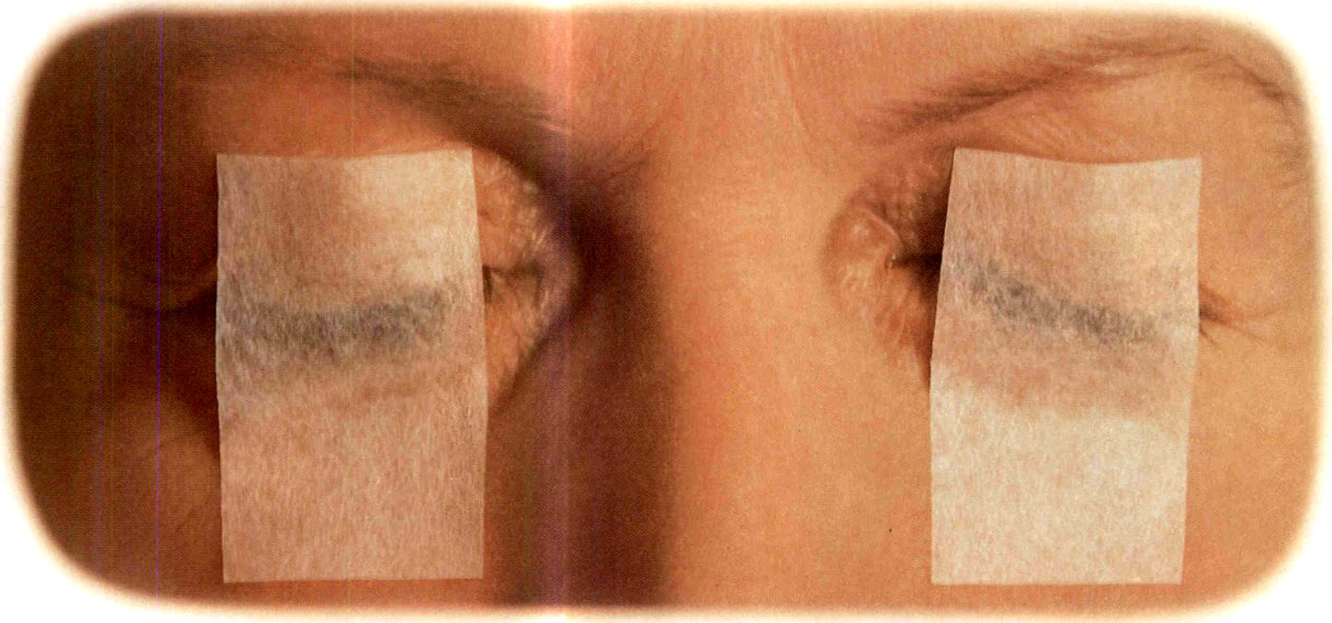

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Anaesthesia, 1992, Volume 47, pages 285–286

Editorial

Steroid anaesthesia

Last year was the 50th anniversary of Selye's paper [1] on the anaesthetic properties of steroid hormones and over the years there have been recurring bursts of enthusiasm for different members of this chemical group. The common factor which the steroids appear to share as anaesthetics is their lack of toxicity and overall safety. The other general observation made by Selye was that all these drugs were detoxified in the liver, which has been confirmed for later steroid anaesthetics.

Selye had originally thought that only hormonally active substances were active as anaesthetics, thus excluding, for instance, cholesterol. However, in the following year [2] he showed that the two properties could be separated and indeed that there was a structure/function relationship. The presence of an oxygen atom at either end of the steroid molecule was necessary and double bonds in the A or B rings decreased anaesthetic activity (e.g. cortisol or aldosterone). The most active compound identified by him was pregnanedione but it was almost insoluble in water and therefore difficult to administer intravenously.

There was a long delay before a solution to this problem was found but, with the production of hydroxydione, the sodium succinate derivative of pregnanedione, a water soluble alternative was at last available [3,4]. Early clinical trials of its first form, Viadril, showed that it was less toxic than thiopentone with regard to cardiovascular and respiratory depression. At the same time it produced good jaw relaxation and depression of the laryngeal reflexes enabling the patient to tolerate the tracheal tube readily. Recovery was prolonged but was associated with a sense of well-being and good appetite [5]. Like some of the other steroids, the onset of anaesthesia with hydroxydione was slow and Robertson and Wynn-Williams [6] suggested that one or more metabolites could be responsible for its anaesthetic activity. While this was never proved it led to continued research on the steroid grouping.

Clinical studies of hydroxydione soon gave evidence of pain on intravenous injection and thrombophlebitis in the vein concerned [4]. This could only be avoided by injection of a large volume of the 2.5% solution into a fast-running infusion ('pouring through the drip chamber like a running tap' [5]) or by the use of as much as 500 ml of dilute solution (0.5% or weaker). This inevitably slowed down the induction of anaesthesia even further. Many methods of preventing the venous irritation with hydroxydione were tried, including the use of a different formulation (Pressuren). This was easier to dissolve but thrombophlebitis was still encountered [5]. These problems not only led to the abandonment of hydroxydione but suggested that other water-soluble steroids would be unsatisfactory and that research should turn again to fat-soluble steroids. The next phase of the work by Glaxo Research [7] looked at 168 variants of pregnanedione. One of these, which was otherwise promising (a phosphate derivative of hydroxydione), caused extremely unpleasant paraesthesia from head through the trunk and down into the legs. It was therefore abandoned and work slowly proceeded with other steroids. The most promising involved the 3 α-hydroxy form of the steroid, substitution of the α for the β isomer at the 5 position and oxygenation of the 11 position of the original pregnanedione molecule, small changes but sufficient to yield a potent and rapid-acting anaesthetic which was nonirritant and could be solubilised in the currently established fat solvent Cremophor EL. The new anaesthetic was known as Althesin, the active ingredients of which were two closely related steroids known as alphaxalone and alphadolone acetate. The latter in fact has minimal anaesthetic potency and was only used to improve the solubility of the alphaxalone in Cremophor.

The Althesin steroids shared the properties of their predecessors in having a wide safety margin [8] (Table 1) in being rapidly metabolised in the liver, and associated with a pleasant recovery. Unlike hydroxydione, Althesin was rapid-acting and in its Cremophor solvent was nonirritant on injection. The problems of Cremophor need not be reviewed here, since they have recurred with each preparation with which it has been used. Unfortunately, alphaxalone was never tried clinically in any other solvent so its true place may well have been lost unjustifiably.

Glaxo Research persisted in its efforts to find a water-soluble steroid which would not require problematic solubilisers and minaxolone, which involved further changes to the pregnanedione molecule, did appear to be worthy of clinical trials. However, early studies showed that recovery was unexpectedly prolonged and that there was an unacceptably high frequency of muscle movement [9,10]. Soon afterwards, equivocal toxicological findings in rats led to its withdrawal. Since all recent work has been towards more short-acting drugs, this was probably wise, but it unfortunately meant that Glaxo lost interest in the development of steroid anaesthesia.

For some years a soya bean emulsion had been marketed by Kabivitrum for parenteral nutrition and

Table 1. Therapeutic index measured by two groups with steroid and other anaesthetics.

	Mice [8]	Rats [14]
Hydroxydione	17.3	—
Althesin	30.6	28.7
Pregnanolone	—	40.0
Thiopentone	6.9	4.6
Propofol	—	5.1
Midazolam	—	6.8

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in 1976 [11] it was introduced as a solvent for diazepam. It soon appeared that here was a solvent which was locally nonirritant and was not associated, alone or in combination, with hypersensitivity reactions. Its use became well established when the current final preparation of propofol was formulated and it seems likely that we now have a safe solvent for any intravenous anaesthetics of low water-solubility.

Pregnanolone (3α-hydroxy-5β-pregnane-20-one), a metabolite of progesterone, has been known to be anaesthetically active as far back as 1957 [12]. However, the problem of finding a suitable solvent and the economics of marketing a naturally occurring substance as an anaesthetic, restricted its clinical use until 1990 when volunteer studies began in Copenhagen [13]. The drug has already been shown to have the highest therapeutic index of any of the drugs studied [14] (Table 1) and the volunteer and early clinical studies reported below, confirm this safety in broad terms. Interestingly, it is pharmacologically similar to Althesin, both having an induction dose of approximately 0.6 $mg.kg^{-1}$ and anaesthesia being induced in one arm–brain circulation time [15]. The finding of tachycardia, and a low incidence of involuntary muscle movements, also occurs with Althesin and the barbiturates.

Volunteer and clinical studies have now been carried out with pregnanolone in sufficient numbers to indicate that we have here a safe and useful new agent. There is no reason to anticipate unpleasant venous sequelae with the formulation in soya bean emulsion but full studies will clearly be required. Likewise, detailed recovery studies will be needed to evaluate the predictions [13] of less cumulation effects than with any of the barbiturate intravenous agents and rapid recovery without hangover. These studies should include patients with hepatic dysfunction to confirm the role of the liver in the metabolism of this drug. An unusual side effect noted by Carl and his colleagues [13] was pyrexia of 38.3°C without leucocytosis. This could be coincidental but steroid pyrogens are known and this possibility also warrants study. Altogether, while pregnanolone may not be the ideal intravenous anaesthetic, it is a stage in that direction, and its high therapeutic index sets it apart from its nonsteroid rivals.

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Editorial notices

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Anaesthesia, 1992 Volume 47, pages 287–290

Pregnanolone: a new steroid intravenous anaesthetic

Dose-finding study

H. POWELL, M. MORGAN AND J. W. SEAR

Summary

The intravenous steroid anaesthetic pregnanolone has been investigated as an induction agent in 60 fit adults premedicated with morphine and atropine. The drug was given in a stepwise fashion starting with 0.5 mg.kg^{-1}; following a successful induction, the next patient received 15% less, while the subsequent patient received 15% more if anaesthesia was not achieved. Taking loss of eyelash reflex as the end point, 31 patients were satisfactorily induced; the AD$_{50}$ in these patients was 0.44 mg.kg^{-1} (95% CI 0.41–0.47). A further 23 patients were induced satisfactorily as assessed by cessation of counting. Induction was trouble free with minimal changes in heart rate and arterial blood pressure, a low incidence of apnoea and few involuntary movements; pain on injection was not a feature. Loss of eyelash reflex is not a good end point for assessment of loss of consciousness following pregnanolone.

Key words

Anaesthetics, intravenous; pregnanolone.
Induction; anaesthesia.
Potency, anaesthetic; AD$_{50}$.

It is now 50 years since Selye [1] described the ability of certain steroid hormones to produce reversible sleep in animals. Of the molecules investigated by Selye, progesterone, pregnenolone and related 5-alpha-pregnane compounds had the greatest potency in rats. However, all of these molecules were insoluble in water and therefore needed formulating in peanut oil.

To date there have been four steroid anaesthetic drugs used clinically. Hydroxydione [2], a water soluble hemisuccinate ester of 5-beta-pregnanedione, produced anaesthesia, but was associated with a number of undesirable effects such as pain on injection, prolonged onset and duration of action and a high incidence of thrombophlebitis [3, 4]. A further compound, 3-alpha-OH 5-beta-pregnanedione 3 phosphate sodium salt, was investigated in animals and in man. There was no pain on injection or thrombophlebitis, but there was a delay in the onset of sleep and patients complained of paraesthesia in the arms and neck prior to the production of anaesthesia [5].

Althesin (3-alpha-OH 5-alpha-pregnane-11, 20-dione and its 21 acetoxy derivative: alphaxalone, alphadolone acetate) provided rapid onset of anaesthesia and rapid recovery, with minimal cardiovascular depression [6], but had the severe disadvantage of precipitating anaphylactoid responses, probably due to the vehicle used as a solvent for the drug, cremophor EL [7, 8].

A fourth compound, minaxolone citrate (11-alpha-*N*, *N*-dimethyl amino 2-beta-ethoxy-3-alpha-OH 5-alpha-pregnane-20-one citrate) was a water-soluble steroid providing satisfactory anaesthesia, but recovery was slower than after Althesin [9, 10]. However, it was withdrawn whilst undergoing clinical trials because of concerns over potential carcinogenicity.

The present agent, 5-beta-pregnanolone, was one of the steroid molecules shown by Gyermek *et al.* [11] to possess significant anaesthetic potency in a number of animal species. Until recently, its water insolubility prevented its use in man. It is now formulated as an emulsion as pregnanolone 4 mg, soya bean oil 200 mg, acetyl triglycerides 70 mg, egg yolk phosphatides 18 mg, glycerol 17 mg and distilled water to a volume of 1 ml. The emulsion is isotonic, with a pH around 7.5.

We report here the initial clinical evaluation of this drug in 60 patients in two centres (Hammersmith Hospital, London and John Radcliffe Hospital, Oxford) as part of a dose finding evaluation.

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Methods

The study was carried out in 60 ASA 1 or 2 patients, using an identical protocol in each centre. Patients were male or female of nonchildbearing potential, aged between 18 and 65 years and with weights within 20% of the expected normal for height. All patients gave written informed consent to the investigation, which was approved by the Committee on Safety of Medicines, and by the respective local ethics committees.

Premedication consisted of morphine 0.1 mg.kg^{-1} (to the nearest 5 mg) and atropine 0.6 mg intramuscularly given 30–60 min pre-operatively. An indwelling cannula was inserted into a dorsal hand vein after which the patient was allowed to rest for 5 min in the anaesthetic room. Pregnanolone was then injected using a predetermined dosage regimen which varied according to the method described by Dixon and Massey [12]. The initial dose used in both centres was 0.5 mg.kg^{-1}, as suggested by preliminary work in volunteers [13]. Doses were increased or decreased by 15% in subsequent patients in accordance with the response. Thus if satisfactory anaesthesia was achieved in a patient, the next patient received that dose minus 15%; if anaesthesia was not induced, the next patient received that dose plus 15%, and so on.

Pregnanolone was injected over 20 s, and a satisfactory induction was deemed to have occurred if there was loss of the eyelash reflex within 120 s of the start of the injection. If the eyelash reflex persisted, induction was regarded as a failure and thiopentone was given in 50 mg increments until anaesthesia was induced. The patient was also asked to count during induction, and time to cessation of counting from the start of the injection was also recorded. Patients breathed air or oxygen for 3 min after the start of pregnanolone injection; thereafter, nitrous oxide 67% in oxygen and isoflurane 0–2% were introduced. Surgery was not started for 10 min after the induction of anaesthesia.

The electrocardiogram (ECG), with heart rate and pulse oximetry were recorded throughout anaesthesia. Arterial blood pressure was measured noninvasively 1 min before induction and then at 1, 2, 3, 5, 8, and 10 min from the start of the pregnanolone injection.

Any complaints of pain on injection of pregnanolone were noted. Any involuntary movements or increase in muscle tone were recorded, as were any respiratory disturbances such as coughing, sneezing or hiccoughs. The time and duration of apnoea, if it occurred, were also recorded.

Statistics

Changes in haemodynamic variables and oxygen saturations were compared with baseline values using analysis of variance (ANOVA, Dunnett test). Successful induction times are shown as median (range). All other data are reported as mean (SD). A p-value of < 0.05 was assumed to indicate a significant difference.

Results

Demographic data of the patients are shown in Table 1, together with the premedication–induction intervals. The dose of pregnanolone used varied from 0.29–0.58 mg.kg^{-1}.

Anaesthesia was successfully induced, according to the criterion of loss of eyelash reflex, in 31 patients, in a median time of 65 s (range 32–96 s). However, a further 23 patients were judged to be unconscious as assessed by cessation of counting, but they did not lose their eyelash reflexes within the prescribed time. The time to cessation of counting in these patients varied from 20–110 s (median 31 s).

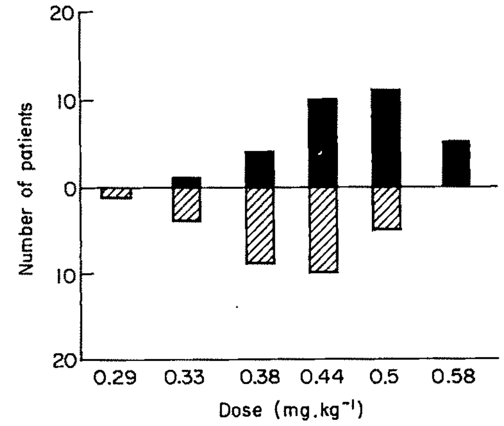

Fig. 1. Number of successful (■, loss of eyelash reflex) and unsuccessful (▨) inductions using different doses of pregnanolone.

The effect of the doses used is shown in Figure 1. Using the formula of Dixon and Massey [12] this gives an AD_{50} value in those in whom the eyelash reflex was lost, of 0.44 mg.kg^{-1} (95% CI 0.41–0.47).

The haemodynamic changes in those who were satisfactorily induced (loss of eyelash reflex within 120 s) are shown in Figure 2. There was a small but statistically significant decrease in both systolic and diastolic arterial pressures during the 3 min period from the start of pregnanolone injection. Heart rate increased significantly 30 s after the start of drug administration, but thereafter returned to baseline level by 3 min. Oxygen saturation remained satisfactory throughout the study period.

Complications occurring during induction are shown in Table 2. Apnoea occurred in seven patients. In three it was associated with a dose of 0.38 mg.kg^{-1} (duration 35, 60 and 75 s), in two with a dose of 0.44 mg.kg^{-1} (60 and 125 s) and in a further two who received 0.5 mg.kg^{-1} (10 and 15 s). Hypertonus of the jaw and limbs occurred in six patients, in only two of whom was anaesthesia successfully

Table 1. Demographic data, presented as mean (SD).

n	60
Males	31
Age; years	42.7 (11.7)
Weight; kg	69.3 (12.2)
Premed–induction interval; min	69.1 (41.2)

Table 2. Untoward events associated with onset of anaesthesia.

Apnoea	7
Hypertonus of jaw/limb	6 4F, 2S
Involuntary movements	8 3F, 5S
ECG changes	1
Discomfort on injection	
Pain	1
Cold	2
Macular rash	1

S, successful induction; F, induction failure.

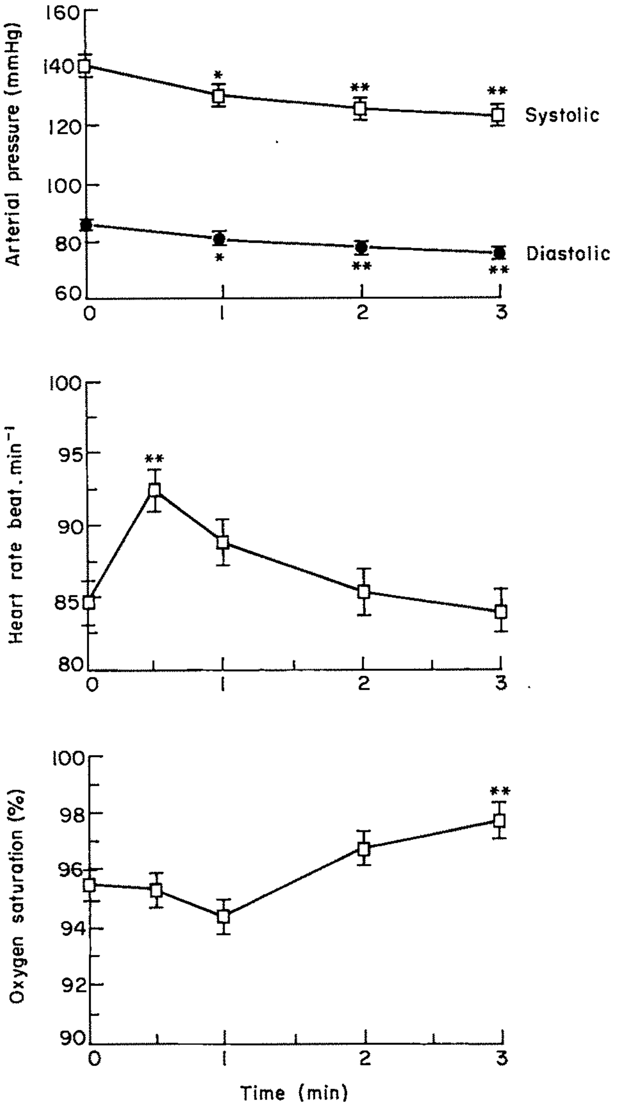

Fig. 2. Arterial blood pressure, heart rate and oxygen saturation during the 3 min following successful induction of anaesthesia with pregnanolone. Values are expressed as mean (SE). Statistically significant changes from pre-induction levels (time 0) *$p<0.05$, **$p<0.01$ (ANOVA).

induced. Involuntary movements were noted in eight patients (five successfully induced) and in seven these consisted of minor twitching. The remaining patient developed tonic–clonic movements in all limbs. These began 90 s after the start of pregnanolone injection and persisted for about 3 min, despite the administration of 250 mg thiopentone. One patient complained of mild pain along the vein during injection, while a further two commented that the injectate was cold.

One 54-year-old woman with treated hypertension developed atrial ectopic beats 1 min after induction, which persisted throughout the operation. A further 43-year-old woman developed a junctional rhythm following the introduction of isoflurane; there were no haemodynamic consequences in either patient. A macular rash developed around the neck line 3 min after injection of pregnanolone in one patient and lasted about 3 min. It was probably unrelated to the study drug, since the ECG electrodes were located in a similar pattern, just below the level of the rash.

In one patient it was necessary to intubate the trachea 4.5 min after induction because of excessive coughing leading to laryngospasm and cyanosis. This was thought to have resulted from a too rapid increase in the inspired isoflurane concentration.

Discussion

During the course of this study, it became obvious that loss of the eyelash reflex was not a reliable sign of loss of consciousness following administration of pregnanolone. Only 31 patients were judged to be anaesthetised within 120 s utilising this sign. If cessation of counting had been the primary end point, then a further 23 patients would have been satisfactorily induced. The unreliability of loss of eyelash reflex when judging the onset of loss of consciousness has been noted previously with other intravenous agents [14]. Using the primary end point, the AD_{50} of pregnanolone was 0.44 mg.kg^{-1}.

The initial dose of 0.5 mg.kg^{-1} was chosen following previous work in volunteers [13]. In that study, which involved six unpremedicated subjects, sleep was achieved in all who received 0.6 mg.kg^{-1}, but in only one of two subjects given 0.5 mg.kg^{-1}. Since our patients were premedicated, it was decided to use an initial dose of 0.5 mg.kg^{-1}.

Induction with pregnanolone was remarkably trouble free. The involuntary movements that were observed were minor and of no clinical significance. Similarly, the hypertonus observed in six patients was minor and of short duration. In the one patient who had myoclonic movements, anaesthesia was successfully induced but generalised involuntary movement began 20 s later. Thiopentone administration produced no immediate reduction in this involuntary activity, which only settled after the introduction of isoflurane and deepening anaesthesia. There was no apnoea.

Pain on injection is not a feature of induction with pregnanolone. All injections were made into the small veins on the back of the hand; only one patient complained of mild pain. This is a distinct advantage of pregnanolone over other intravenous agents such as methohexitone, propofol and etomidate.

Induction with pregnanolone was associated with relatively little change in arterial blood pressure. Although the reduction in arterial pressure of 12% was statistically significant, this was not of any clinical relevance. There was a significant increase in heart rate, averaging 8 beat.min^{-1}, immediately after induction, but this had returned to within 2 beat.min^{-1} of baseline by 2 min after induction. Such increases in heart rate are common following induction of anaesthesia, and have been reported after thiopentone and in particular methohexitone [15] and minaxolone [9]. Changes in heart rate following propofol [16] and etomidate [17] are minor and usually insignificant.

Apnoea, ranging from 10 to 125 s, was observed in seven patients, after doses of pregnanolone which varied from 0.38 to 0.5 mg.kg^{-1}. Again, this finding is in keeping with other intravenous anaesthetics [9, 10, 15, 16].

This study attempted only to evaluate the induction characteristics of pregnanolone and to discover an acceptable dose. We were impressed with the trouble free induction of anaesthesia that was achieved, but suggest that loss of eyelash reflex is not an appropriate end point for use with this agent. We believe the pregnanolone warrants further evaluation as an intravenous induction agent.

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Tramadol: pain relief by an opioid without depression of respiration

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Summary

Two independent clinical trials were conducted simultaneously. In one, tramadol and pethidine were compared in 30 patients by patient-controlled analgesia during the first 24 h following abdominal surgery. The mean 24 h consumption of tramadol and pethidine was 642 mg and 606 mg respectively, giving a potency estimate of tramadol relative to pethidine of 0.94 (95% confidence interval 0.72–1.17). In the second trial, the effect on respiration of three doses of tramadol (0.5, 1.0, and 2.0 mg.kg^{-1}*) was compared with that of morphine sulphate (0.143 mg.kg*$^{-1}$*) by intravenous injection during stable halothane anaesthesia. At approximately 1.5 times the equipotent dose, as estimated from the first trial, tramadol transiently depressed the rate of respiration but had no effect on end-tidal carbon dioxide tension. Morphine caused apnoea or considerable depression of ventilation. The results suggest that mechanisms other than opioid receptor activity play a significant role in the analgesia produced by tramadol.*

Key words

Analgesia; postoperative, patient-controlled.
Analgesics; morphine, pethidine, tramadol.
Measurement techniques; spirometry, gas analysis, visual analogue scores.

When a pharmaceutical company approaches an experienced research worker with the story that they have an analgesic drug, with activity at μ-opioid receptors but which does not depress respiration, the response is likely to be the scientific equivalent of 'pull the other one'. It is a claim which has often been made but never really substantiated.

The work described in this paper was part of a 'crash' programme of studies undertaken in response to such a claim for tramadol, a drug available in Germany since 1977 and marketed in many other countries throughout the world since then, for which a British partner company wished to obtain a Product Licence in the United Kingdom. The ensuing research programme, born initially of some scepticism, attempted to compare this drug in four different but relevant ways with existing standard drugs. These were, (i) a relative potency estimate against pethidine by patient controlled analgesia (PCA), a method of which we had considerable experience [1] and against a drug for which we had previous data [2–4], (ii) a comparison with morphine (and saline) on the effect of three different doses on respiratory parameters when given intravenously during halothane anaesthesia (again a method with which we had previous experience) [5], (iii) a comparison with codeine as a cough suppressant against ammonia inhalation and (iv) a comparison with morphine (and placebo) on gut motility after minor gynaecological surgery. For various reasons, neither of the two latter trials produced statistically significant results. However, the first two bear most on the point at issue, namely the respiratory depressing potential of tramadol versus other similar analgesics at equipotent doses. Even though, unfortunately, for what seemed good reasons at the time, these two studies were carried out using different comparators, it seems logical to describe the results in one paper.

Tramadol is an unusual compound. Although it is a weak agonist at all types of opioid receptor [6] with some selectivity for μ-receptors it also causes *in vitro* inhibition of neuronal noradrenaline uptake [7] and serotonin release [8, 9]; these are transmitters in descending inhibitory pathways which enhance analgesia. The drug is produced as a racemic mixture and the two isomers have different spectra of activity, the L-isomer being more active at the opiate receptor and the D-isomer at other sites [10].

Previous studies of the respiratory effects of tramadol have given conflicting results, some authors concluding that

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there is a depressant effect [11], and others concluding that there is not [12–14]. It seemed important, therefore, to establish its analgesic potency so that it could be evaluated in clinically realistic equipotent doses. Patient controlled analgesia (PCA) is an economical way of evaluating relative analgesic potency [1] and accordingly it was decided to evaluate tramadol against pethidine following abdominal surgery.

Assessment of the respiratory effect of drugs in a patient anaesthetised with halothane renders the respiratory centre more susceptible to depression and provides a sensitive test system with which to unmask minor respiratory depressant actions of a drug [5].

Methods

Comparative potency study

Thirty patients presenting for elective gynaecological surgery, ASA Class 1 or 2, and between 18 and 70 years of age were entered into the trial which had been approved by the local ethics committee. The patients were visited on the day before surgery to obtain written informed consent and were instructed in the use of the PCA device. They were also introduced to the concept of the linear analogue scale to record pain and other subjective sensations [15]. The patients were premedicated with diazepam 0.15 $mg.kg^{-1}$ administered orally 1 h before operation. Anaesthesia was induced by intravenous thiopentone 4–5 $mg.kg^{-1}$ and tracheal intubation was facilitated using suxamethonium or a nondepolarising relaxant. Anaesthesia was maintained with oxygen, nitrous oxide and enflurane (0.5–2%) supplemented with a maximum of 0.2 mg of fentanyl, depending on clinical need. Residual neuromuscular blockade was antagonised using atropine and neostigmine. All the operations were undertaken through lower abdominal incisions and lasted between 1 and 3 h, the majority being hysterectomies.

Because we had data on pethidine consumption in similar clinical circumstances from three previous double-blind trials, it was decided to allocate patients in a ratio of 2:1, double-blind, to receive either tramadol or pethidine for 24 h after the operation. On arrival in the recovery ward, an AbbottLife care PCA device was connected to the intravenous infusion, using a valved-Y-Cardiff connector [16]. The PCA device was set to deliver incremental doses of either tramadol 20 mg or pethidine 20 mg given as 1 ml of solution. The minimum interval between successful responses to demands (lock-out time) was set at 5 min for the first hour and at 10 min thereafter. On awakening and requesting analgesia, the patient was given the demand control hand-switch and reminded how to use it. Patients were assisted if necessary and were kept in the recovery ward until proficient in the use of the PCA device; they were then returned to a high dependency unit to self-administer analgesia for 24 h. Times at which the analgesic doses were demanded, and whether or not they were successful, were recorded on an event recorder.

Indirect arterial blood pressure, heart rate and respiratory rate were recorded by the nursing staff. Metoclopramide 10 mg intravenously was prescribed for any patient who complained of severe nausea or who vomited, and an alternative analgesic regimen (pethidine 75 mg intramuscularly) was provided as escape medication if the on-demand system was rejected.

The patients were visited 24 h after surgery, at which time the delivery system was discontinued and they were asked to mark linear analogue scales representing pain at rest, pain on movement and degree of sedation. The linear analogues for pain ranged from 'none' on one end to 'the worst pain imaginable' at the other. For sedation the extremes were 'wide awake' and 'just on the point of falling asleep'. They were asked to place the mark to represent an average of the relevant sensation over the whole 24 h period.

Differences between treatments were compared by an unpaired Student's t-test for total analgesic consumption and by Mann–Whitney U-test for visual analogue scores. The analgesic potency of tramadol relative to pethidine was estimated by the ratio of the mean 24 h consumptions together with its 95% confidence interval.

Respiratory effects study

After ethics committee approval had been obtained, 30 patients, ASA Class 1 or 2, aged 18–60 years were recruited. All were scheduled to undergo elective surgery involving tracheal intubation. Exclusion criteria included pregnancy, weight of more than 85 kg and use or abuse of agents which act on the central nervous system. All patients were visited on the day before surgery and written informed consent was obtained.

Premedication was with diazepam 10 mg given orally 1 h before arrival in the anaesthetic room. An intravenous infusion was set up and noninvasive monitoring of blood pressure, ECG, and pulse oximetry started. General anaesthesia was induced with a sleep dose of thiopentone; suxamethonium was given to facilitate tracheal intubation. Anaesthesia was maintained with nitrous oxide, oxygen

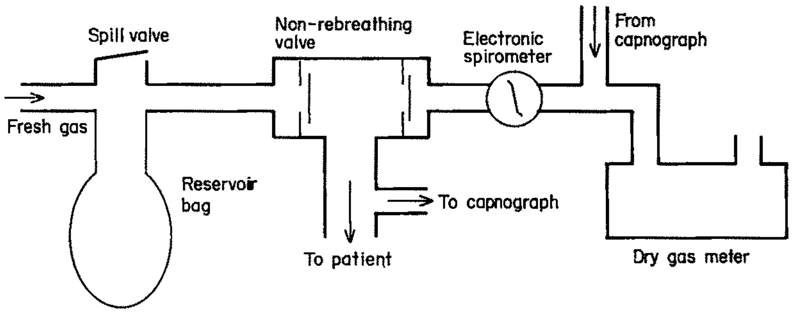

Fig. 1. The breathing system.

and halothane 1%. Manual ventilation was maintained until the return of spontaneous ventilation and then the patient was connected to the nonrebreathing system illustrated in Figure 1. Throughout the experimental period, the patient remained in a quiet anaesthetic room.

The expired gas passed via an Ambu nonrebreathing valve through an electronic spirometer (Magtrak vane anemometer), to a Parkinson Cowan dry gas meter. A capnograph sampled gas at 50 ml.min^{-1} at the end of the tracheal tube. Readings were taken from the display on each instrument, and, in addition, a record of the spirometer and capnograph output was made on a chart running at 25 mm.min^{-1}. The accuracy of the Magtrak was found to depend on flow and readings were only used for analysis when respiration had to be assisted and minute volume readings were not possible.

At the start of each study the capnograph was calibrated using a reference gas. Tidal volume was read from the spirometer by recording the modal value displayed over five consecutive breaths. The accuracy of the dry gas meter was checked using a syringe of known volume and was used to measure minute volume. The time for the patient to exhale 10 l was recorded and from this the minute volume was calculated.

Patients were randomised, six each to one of five treatment groups. To enable the investigator to remain blind to the treatment group, the active drug was diluted by another doctor so that each patient received 0.1 ml.kg^{-1} of solution. When the respiratory parameters had been constant for 10 min, the treatment solution was given intravenously over 30 s. Group 1 received 0.1 ml.kg^{-1} of normal saline; group 2, morphine sulphate 0.143 mg.kg^{-1} (equivalent to a dose of 10 mg.70 kg^{-1}); group 3, tramadol 0.5 mg.kg^{-1}; group 4, tramadol 1 mg.kg^{-1}; group 5 tramadol 2 mg.kg^{-1}. Recordings of respiratory variables were made just prior to the injection and then at 5 min intervals for 30 min.

If the end-tidal $P\text{CO}_2$ ($P\text{E}'\text{CO}_2$) rose above 60 mmHg, ventilation was manually assisted to keep $P\text{E}'\text{CO}_2$ at 60 mmHg. When a measurement was due, the manual assistance to ventilation was temporarily stopped and tidal volume and the $P\text{E}'\text{CO}_2$ measured over six breaths. The lungs of any patient who stopped breathing for more than 30 s were manually ventilated; they were then given naloxone 0.2 mg, which was repeated after 5 min if necessary. At the end of the 30 min monitoring period, the anaesthetic technique was adjusted as necessary and the patient was taken into the operating theatre.

From the series of six postdrug recordings the maximum values for $P\text{E}'\text{CO}_2$ and minimum values for respiratory rate and minute volume were identified. The differences between the baseline readings and the maximum or minimum value were submitted to one-way analysis of variance. If the overall difference between the five treatments achieved statistical significance at the 5% level, then the difference between each treatment and each of the others was tested individually for significance at the same level by Student's *t*-test.

Results

Comparative potency study

The two groups were comparable in age, height and weight (Table 1).

Table 1. Mean (SD) and range of age, height and weight of patients in the study of comparative potency.

		Tramadol ($n = 20$)	Pethidine ($n = 10$)
Age; years	Mean	37 (8)	41 (8)
	Range	23–52	28–53
Height; cm	Mean	160 (7)	162 (5)
	Range	150–178	153–168
Weight; kg	Mean	64 (11)	66 (12)
	Range	47–91	51–86

The mean 24 h consumptions of tramadol and of pethidine were respectively 642 (SD 190 mg, range 180–840 mg) and 606 (SD 172 mg, range 360–780 mg). The estimate of relative potency of tramadol to pethidine was 0.94 (95% confidence interval: 0.72–1.17). One patient in the tramadol group received two intramuscular injections of 75 mg pethidine as escape analgesia because the PCA unit had been inadvertently switched off. For this patient, the consumption of tramadol was estimated as: 680 mg (actual consumption) + 150 mg/0.94 = 840 mg.

The marks on the 10 cm visual analogue scales were converted to a score in centimetres, measured from the left hand of the scale. Thus higher scores represent more pain or more sedation. The mean scores are given in Table 2.

The mean pain score for pethidine was higher than for tramadol for both pain at rest and pain on movement: in no case, however, was the difference statistically significant. There was a more marked difference in sedation scores; tramadol patients claimed to be less sedated, but this difference only approached statistical significance ($p = 0.07$) in this number of patients.

There were no statistically significant differences between the groups for changes in pulse rate, respiratory rate and temperature. For blood pressure the mean systolic and diastolic levels in the tramadol group increased by 3.8/3.8 mmHg compared with a mean decrease in the pethidine group of 7.5/2.0 mmHg. This difference, although not clinically important, was statistically significant for both systolic and diastolic pressures.

Nausea was the most frequent postoperative symptom, occurring in 6/20 patients in the tramadol group and 4/10 in the pethidine group, all of mild to moderate severity. Two patients vomited in each group. There were three cases of undue somnolence, one in the tramadol group and two in the pethidine group. Other symptoms were few and only mild or moderate.

Respiratory effects study

Details of the patients are given in Table 3. One patient in the morphine group became apnoeic and was given two

Table 2. Mean (±SD) and range of the visual analogue scores.

		Tramadop ($n = 20$)	Pethidine ($n = 10$)	p
Analgesia at rest	Mean	2.6 (2.3)	2.7 (1.9)	0.88
	Range	0.2–8.6	0.2–6.5	
Analgesia on movement	Mean	4.0 (2.6)	5.2 (1.7)	0.21
	Range	0.8–9.2	2.9–8.3	
Sedation	Mean	4.7 (2.6)	6.6 (2.6)	0.069
	Range	1.1–9.5	0.5–9.9	

Table 3. Characteristics of patients in the respiratory depression study (mean and range).

	Male/female	Age; years	Height; cm	Weight; kg
Placebo	3/3	33	169	70
		23–47	158–180	54–85
Morphine (0.143 $\mathrm{mg.kg^{-1}}$)	3/3	38	169	70
		21–59	151–186	51–85
Tramadol (0.5 $\mathrm{mg.kg^{-1}}$)	3/3	39	171	69
		30–50	157–188	55–85
Tramadol (1 $\mathrm{mg.kg^{-1}}$)	1/5	38	159	57
		21–57	152–171	43–66
Tramadol (2 $\mathrm{mg.kg^{-1}}$)	2/4	36	164	68
		27–43	152–180	57–85

doses of naloxone 0.2 mg before spontaneous respiration returned. In this patient, values for the response variables were possible only at 5 min. Two further patients, one in the morphine group and one in the tramadol 0.5 $\mathrm{mg.kg^{-1}}$ group required manual ventilation in order to maintain end-tidal $P\mathrm{CO}_2$ below 8.0 kPa. In these two patients, the measurement of minute volume was derived from tidal volume and frequency following the test drug injection. One patient in the morphine group was omitted from the analyses. This patient showed, if anything, a slight rise in respiratory rate and minute volume after the injection of the test solution and subsequent checking cast doubt on whether the third party making up the solution blind had understood the instructions. We believe that the active drug was not included.

Respiratory rate

The mean results in each group for each time interval are plotted as differences from baseline by treatment and time in Figure 2, and the statistical analysis is laid out in Table 4.

The respiratory rate tended to decrease within 5 min of the injection of the test drug, particularly for morphine and tramadol 2 $\mathrm{mg.kg^{-1}}$. The minimum respiratory rate in the five treatments differed statistically significantly. There was also a significant tramadol dose-response relationship.

End-tidal CO_2

The mean results for $P\mathrm{E'CO}_2$ are plotted in Figure 3 by treatment and time and the statistical results presented in Table 5. The maximum change observed after morphine cannot be regarded as the true maximum response as the value was still rising 30 min after injection. For the maximum end-tidal CO_2 there was a statistically significant difference between the five treatment groups, but no evidence of a dose–response relationship for tramadol. The source of the overall difference was the effect of morphine compared with the other treatments.

Minute volume

Table 6 summarises the results and the statistical analysis of the minute volume measurements. There was an overall difference between the five groups for the difference between baseline and the minimum value ($p = 0.02$), due to the marked effect of morphine, but no evidence of a dose–response relationship for tramadol.

Table 4. Mean (SD) of the respiratory rate ($\mathrm{breath.min^{-1}}$).

	Baseline	Minimum	Minimum–baseline	
Placebo	28.5 (3.9)	27.8 (3.9)	−0.7 (0.8)	A
Morphine (0.143 $\mathrm{mg.kg^{-1}}$)	24. 3 (3.5)	14.7 (6.1)	−9.7 (5.2)	B
Tramadol (0.5 $\mathrm{mg.kg^{-1}}$)	29.7 (4.0)	25.0 (2.4)	−4.7 (3.4)	C
Tramadol (1.0 $\mathrm{mg.kg^{-1}}$)	29.0 (5.3)	25.5 (3.8)	−3.5 (3.4)	D
Tramadol (2.0 $\mathrm{mg.kg^{-1}}$)	29.8 (4.2)	22.2 (2.5)	−7.7 (2.0)	E

A-B significant at $p < 0.001$: B-D and A-E significant at $p < 0.01$: A-C, B-C significant at $p < 0.05$: C-D-E dose response relationships significant at $p < 0.01$.

Table 5. Mean (SD) $P\mathrm{E'CO}_2$ (mmHg).

	Baseline	Maximum	Maximum–baseline	
Placebo	52.5 (8.0)	55.5 (6.9)	3.0 (2.1)	A
Morphine (0.143 $\mathrm{mg.kg^{-1}}$)	51.8 (4.0)	61.3 (5.5)	9.5 (3.6)	B
Tramadol (0.5 $\mathrm{mg.kg^{-1}}$)	47.8 (4.8)	52.5 (8.0)	4.7 (3.4)	C
Tramadol (1 $\mathrm{mg.kg^{-1}}$)	47.7 (3.6)	51.8 (4.1)	4.1 (1.2)	D
Tramadol (2 $\mathrm{mg.kg^{-1}}$)	47.7 (4.5)	51.8 (7.1)	4.2 (4.1)	E

A-B, B-D, B-E, significant at $p < 0.01$: B-C significant at $p < 0.05$: all other comparisons including dose response relationships: not significant.

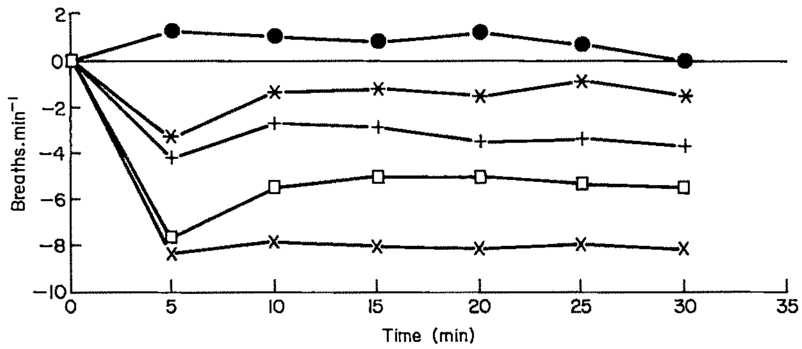

Fig. 2. Respiratory rate: mean difference from baseline. —●—, placebo; +, tramadol 0.5 mg.kg^{-1}; ✱, tramadol 1 mg.kg^{-1}; —□—, tramadol 2 mg.kg^{-1}; ×, morphine 0.143 mg.kg^{-1}.

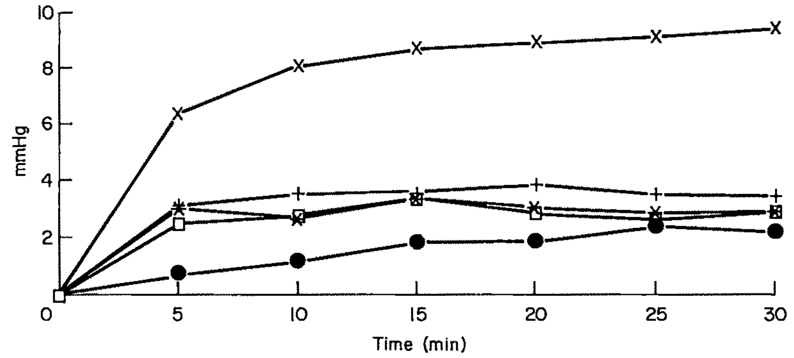

Fig. 3. End-tidal CO_2: mean difference from baseline. Symbols as in Figure 2.

Discussion

The tramadol/pethidine potency ratio, although obtained on relatively few patients, can be accepted with reasonable confidence. The mean 24 h consumption of pethidine at 606 mg closely matches our previous findings for the mean consumption of pethidine after cholecystectomy of 595 mg [2], 570 mg [3] and 614 mg [4] in three double-blind trials. It also accords with a 1:1 ratio found in another similar trial by Lehmann *et al.* [17]. Furthermore, the patients were all undergoing similar operations, the pharmacokinetic profiles of the drugs are similar when given intravenously and the side effect profiles proved fairly similar also. These are important restrictions on the validity of PCA comparisons.

Visual analogue scores showed no statistically significant difference between the two drugs, although there was a trend towards better analgesia on movement with tramadol. The mean scores for pain on movement (4.0 with tramadol and 5.2 with pethidine) represent good levels of analgesia, and are lower than those reported by patients receiving standard intramuscular analgesia for similar operations [18]. The lower mean score for sedation, and the lower incidence of nausea and vomiting with tramadol, although not significant in the small numbers, are potentially useful features.

Table 6. Mean (SEM) minute volume (l.min^{-1}).

	Baseline	Baseline–minimum
Placebo	4.5 (1.0)	0.37 (0.25)
Morphine (0.143 mg.kg^{-1})	4.6 (1.78)	2.21 (1.58)*
Tramadol (0.5 mg.kg^{-1})	4.8 (1.10)	0.76 (1.04)
Tramadol (1 mg.kg^{-1})	4.3 (1.76)	0.50 (0.43)
Tramadol (2 mg.kg^{-1})	4.9 (0.50)	0.95 (0.56)

*Significant at $p < 0.01$. All other comparisons, including dose effects of tramadol, not significant.

The small but statistically significant difference in blood pressure between the two groups may be due to noradrenaline uptake inhibition by tramadol, but in the cardiovascular system the effect is clearly minimal.

In the study of the effects on respiration, tramadol demonstrated advantages over morphine. With both morphine and the largest dose of tramadol there was a rapid fall in respiratory rate, most of the changes occurring during the first 5 min postinjection. In the morphine group there was an immediate rise in $PE'CO_2$ which continued to rise slowly throughout the measurement period but in the tramadol groups no further change was seen after the initial 5 min period. The small rise with placebo indicates that the 'steady state' was actually a slowly increasing depth of anaesthesia.

Using the potency ratio of tramadol relative to pethidine as 1:1, and the accepted potency ratio of morphine to pethidine of 1:10, the dose of morphine used in this study can be considered as equi-analgesic with about 1.5 mg.kg^{-1} of tramadol. A single intravenous bolus of a bigger dose of tramadol than this caused a short-lived reduction in respiratory rate but no sustained change occurred in $PE'CO_2$. In contrast, following morphine it was still increasing at the end of the 30 min study period.

We conclude therefore, that an equi-analgesic dose of tramadol has much less effect on the respiratory centre than morphine; it thus has a higher therapeutic ratio and furthermore its effects are transient. Since tramadol has virtually no dependence potential [19] and is not a controlled drug in most of the countries in which it is currently marketed, it is encouraging that tramadol was well tolerated and equipotent to pethidine in the treatment of postoperative pain following abdominal surgery. On the evidence of these comparisons, it seems likely that tramadol analgesia relies to a considerable extent on non-opioid receptor mechanisms.

Acknowledgment

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Gastric emptying after minor gynaecological surgery

The effect of anaesthetic technique

M. C. MUSHAMBI, D. J. ROWBOTHAM AND S. M. BAILEY

Summary

Gastric emptying was measured using the paracetamol absorption method in 30 patients immediately after a general anaesthetic for minor gynaecological surgery and in 10 female controls. Anaesthesia was induced with either propofol alone, propofol and alfentanil (4.5 μg.kg^{-1}) or propofol and fentanyl (1.4 μg.kg^{-1}) and maintained with intermittent propofol and 66% nitrous oxide in oxygen. Gastric emptying was delayed significantly in all patient groups when compared with volunteers. However, the delay in gastric emptying was similar in the three patient groups.

Key words

Anaesthetics, intravenous; propofol.
Analgesics; alfentanil, fentanyl.
Gastrointestinal tract; gastric emptying.

Delay in gastric emptying in the postoperative period may increase the risk of regurgitation [1] and may delay absorption of drugs administered orally, such as analgesics given after minor surgical procedures. Delayed gastric emptying may also result in gastric distension. Mechanoreceptors are present in the smooth muscle of the stomach wall and stimulation of these may cause nausea and vomiting via vagal afferent neurones [2].

Intermittent intravenous anaesthesia is used frequently for minor gynaecological surgery. Propofol is used extensively, either alone or in combination with an opioid, for anaesthesia during minor gynaecological surgery [3]. There is no information about the effects of these anaesthetic techniques on gastric emptying in the immediate postoperative period. We therefore measured gastric emptying in patients after anaesthesia for minor gynaecological surgery using three intravenous anaesthetic techniques.

Methods

Thirty female patients (ASA 1 and 2) scheduled to undergo elective dilatation of the cervix and curettage were studied and compared with 10 volunteers. The study was approved by the local Ethics Committee and all subjects gave informed written consent.

Patients received no premedication. They were allocated randomly to one of three anaesthetic techniques. Anaesthesia was induced with either propofol 2 mg.kg^{-1}, propofol 2 mg.kg^{-1} and alfentanil 4.5 μg.kg^{-1} or propofol 2 mg.kg^{-1} and fentanyl 1.4 μg.kg^{-1}. Anaesthesia was maintained with 66% nitrous oxide in oxygen and intermittent doses of propofol 20 mg as indicated clinically. All patients breathed spontaneously from a Bain system. Duration of anaesthesia and recovery time were recorded (recovery time was the interval between the last incremental dose of propofol and the time at which the patient opened her eyes to command and was able to give her correct date of birth).

When the patient was able to sit unaided, gastric emptying was measured by the paracetamol method [4].

Table 1. Patient and volunteer characteristics. Mean age (range) and weight (SD). *p < 0.005 compared with patient groups.

Group	*n*	Age (years)	Weight (kg)
Volunteers	10	32.0* (25–42)	61.9 (6.1)
Propofol	10	42.0 (24–51)	62.2 (6.1)
Propofol/ alfentanil	10	39.3 (27–50)	60.3 (8.9)
Propofol/ fentanyl	10	45.2 (27–59)	62.3 (10.5)

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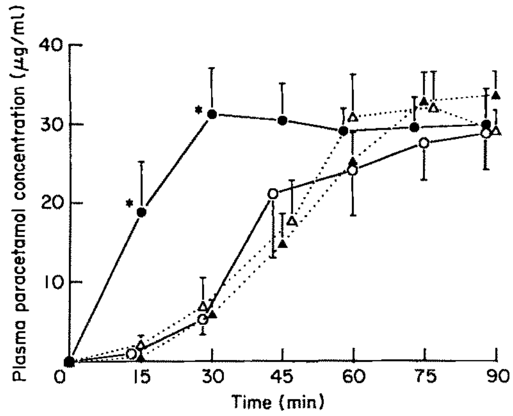

Fig. 1. Mean (SEM) plasma paracetamol concentrations after paracetamol 1.5 g orally, for time 0 to 90 min at 15 min intervals in volunteers (—●—), propofol (—○—), propofol and alfentanil (···△···) and propofol and fentanyl (···▲···) groups.

Paracetamol 1.5 g (three tablets) with water 50 ml were administered orally. After insertion of an indwelling venous cannula, blood 10 ml, for the measurement of plasma paracetamol concentration was taken immediately before paracetamol ingestion and then at 15, 30, 45, 60, 75 and 90 min. Pain was assessed using a four-point scale (0 = no pain, 1 = mild pain, 2 = moderate pain and 3 = severe pain) immediately before each blood sample.

Paracetamol absorption was measured in an identical fashion in 10 female volunteers who were fasted overnight and remained seated during the study.

Plasma was separated immediately and stored at −70°C for subsequent measurement of plasma paracetamol concentrations by high performance liquid chromatography [5]. Lower limit of detection was 0.3 $\mu g.ml^{-1}$ and mean coefficient of variation was 1%.

Data were analysed using one-way analysis of variance followed by Duncan's multiple range test, Chi-squared test and MANOVA for repeated measures as appropriate.

Results

Patient and volunteer characteristics are shown in Table 1. The volunteers were significantly younger than the patient groups ($p < 0.005$) but there was no difference in weight.

There were no differences in the induction and total doses of propofol given, duration of anaesthesia and times to recovery between the three patient groups (Table 2). Mean (SEM) plasma paracetamol concentrations are shown in Figure 1. Paracetamol concentrations were significantly greater in the volunteer group at 15 and 30 min ($p < 0.001$).

Table 2. Mean (SEM) induction and total dose of propofol (mg), duration of anaesthesia and recovery times (min). There was no significant difference.

Group	Induction dose (mg)	Total dose (mg)	Duration of anaesthesia (min)	Recovery time (min)
Propofol	169.9	328.0	10.7	7.9
	(10.5)	(20.2)	(1.4)	(1.8)
Propofol/	156.0	298.0	12.4	7.2
alfentanil	(6.1)	(22.2)	(1.6)	(0.7)
Propofol/	137.6	257.0	10.6	5.9
fentanyl	(12.2)	(16.2)	(1.1)	(1.1)

Table 3. Mean (SEM) AUC_{60} ($\mu g.min.ml^{-1}$), C_{max} ($\mu g.ml^{-1}$) and T_{max} (min). *$p < 0.005$.

Group	AUC_{60}	C_{max}	T_{max}
Volunteers	1427.4*	40.0	60.0
	(226.0)	(5.5)	(8.9)
Propofol	590.9	35.9	73.5
	(189.9)	(5.9)	(5.2)
Propofol/	634.2	37.9	75.0
alfentanil	(168.9)	(3.8)	(3.9)
Propofol/	509.7	37.3	76.5
fentanyl	(97.1)	(3.5)	(4.7)

AUC_{60}, area under the paracetamol absorption curve at 60 min ($\mu g.min.ml^{-1}$); C_{max}, maximum concentration ($\mu g.ml^{-1}$); T_{max}, time to maximum plasma paracetamol concentration (min).

Time to maximum plasma paracetamol concentration (T_{max}), the maximum concentration (C_{max}) and area under the paracetamol absorption curve at 60 min (AUC_{60}) are shown in Table 3. AUC_{60} was significantly greater in the volunteer group ($p < 0.005$).

The distribution of median pain scores over the 90 min study period is shown in Table 4. Pain scores were low and there was no significant difference between patient groups.

Discussion

This study demonstrated a delay in paracetamol absorption in patients who have undergone propofol and nitrous oxide anaesthesia for minor gynaecological surgery with or without alfentanil and fentanyl. The AUC_{60}, which correlates well with the rate of gastric emptying using the scintigraphic method ($r = 0.94$) [6], indicates a delay in gastric emptying in the patient groups compared with volunteers. This was similar in the three patient groups regardless of whether or not the patient received an opioid. However, the delay was not marked, since therapeutic levels of paracetamol were achieved by 90 min.

There is little published data on the effect of intravenous anaesthetic agents on gastric emptying. In a study similar to ours, Reilly and Nimmo showed that 10–15 min after awakening from anaesthesia for cystoscopy with Althesin, nitrous oxide and halothane, paracetamol absorption was

Table 4. Median pain scores. There was no significant difference.

	Patient (%)			
	Median pain score			
Group	0	1	2	3
Propofol	60	30	10	0
Propofol/ alfentanil	80	20	0	0
Propofol/ fentanyl	60	30	10	0

0 = no pain; 1 = mild pain; 2 = moderate pain; 3 = severe pain.

similar to normal volunteers [7]. In contrast, we have shown a delay in gastric emptying with propofol alone and with opioids. The use of opioids would explain these differences [6] but it is unclear why propofol alone should delay emptying compared with Althesin and halothane. Pain delays gastric emptying [8] but the patients in our study complained of little pain (Table 4). Delay may be caused by the effects of gynaecological surgery compared with cystoscopies, but this is speculative.

This study has shown that the use of fentanyl or alfentanil in these doses is not associated with any disadvantages in terms of gastric emptying when compared with propofol alone after minor gynaecological surgery.

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Anaesthesia, 1992, Volume 47, pages 300–302

Cardiovascular responses to insertion of the laryngeal mask

I. G. WILSON, D. FELL, S. L. ROBINSON AND G. SMITH

Summary

We have compared, in 40 healthy patients, the cardiovascular responses induced by laryngoscopy and intubation with those produced by insertion of a laryngeal mask. Anaesthesia was induced with thiopentone and maintained with enflurane and nitrous oxide in oxygen; vecuronium was used for muscle relaxation. Arterial pressure was measured with a Finapres monitor. The mean maximum increase in systolic arterial pressure after laryngoscopy and tracheal intubation was 51.3% compared with 22.9% for laryngeal mask insertion ($p < 0.01$). Increases in maximum heart rate were similar, (26.6% v 25.7%) although heart rate remained elevated for longer after tracheal intubation. We conclude that insertion of the laryngeal mask airway is accompanied by smaller cardiovascular responses than those after laryngoscopy and intubation and that its use may be indicated in those patients in whom a marked pressor response would be deleterious.

Key words

Equipment; laryngeal mask.
Intubation; tracheal.
Complications; hypertension.

The laryngeal mask airway (LMA) [1,2] has proved to be a popular addition to the range of equipment available for airway management. One possible advantage of its use is that insertion of the LMA is associated with a lesser haemodynamic response compared with conventional laryngoscopy and tracheal intubation [3]. To date this has been documented by one study [4], but the authors employed only intermittent measurement of arterial pressure and used an oral airway as part of the technique; this has been shown to be associated with similar cardiovascular responses to those produced by the LMA itself [5], and may have caused difficulty in interpretation of the data. In contrast, Griffin and colleages [6] found no difference in mean systolic arterial pressure and heart rate response between tracheal intubation and LMA insertion. In an attempt to clarify this issue we have also examined the cardiovascular responses to LMA insertion in a group of healthy patients.

Methods

After Ethics Committee approval, informed consent was obtained from 40 ASA 1 patients presenting for elective gynaecological surgery requiring neuromuscular block. Patients with a contraindication to use of the LMA, including those at risk of regurgitation, were not studied. Patients were allocated randomly to a group undergoing tracheal intubation (group 1) or to a group in whom airway control was achieved with a LMA (group 2). Premedication comprised diazepam 10 mg orally 1 h preoperatively. In the anaesthetic room, an 18-gauge cannula was inserted into a dorsal hand vein and monitoring of electrocardiogram (ECG) (lead II), pulse oximetry and expired carbon dioxide (Datex Cardiocap) was started, and a Finapres noninvasive arterial pressure monitor (Ohmeda 2300) was attached. A continuous record of heart rate (HR) and arterial pressure was made from the Finapres onto a chart recorder (JJ Lloyd XY plotter) which was calibrated by the inbuilt signal from the Finapres before each study. After a 5 min stabilisation period, baseline recordings of heart rate and arterial pressure were obtained. Anaesthesia was induced, to loss of eyelash reflex, with thiopentone 4–5 $mg.kg^{-1}$, followed by vecuronium 0.1 $mg.kg^{-1}$, and maintained using manual ventilation of the lungs to normocapnia, via a Bain system, with 67% nitrous oxide and 1% enflurane in oxygen. Four min after induction, either tracheal intubation (with a Mallinckrodt 8.5 mm ID tube) by direct laryngoscopy or LMA insertion (size 3) was performed by the same anaesthetist. A Macintosh size 3 blade was used for all laryngoscopies and the LMA was inserted blindly according to the manufacturers instructions. Recordings were made for

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5 min after intubation or LMA insertion. Thereafter anaesthesia was continued as appropriate.

The arterial pressure and heart rate tracings were analysed after the study. The onset of airway instrumentation was defined as T = 0 and haemodynamic data were obtained at 1-min intervals from T −4 to T +5 and also at T +0.5 min. In addition, the maximum systolic and diastolic pressure and heart rate were recorded for each patient.

The data were analysed using analysis of variance for repeated measures, with Bonferroni *t*-tests.

Results

Data are expressed as mean (SEM), and the percentage changes are the mean of percentage changes calculated for each individual patient. Patient characteristics are presented in Table 1. There were no significant differences between the groups in age or weight. The data from one patient in group 1 and two patients in group 2 were excluded from analysis because of technical difficulties with the arterial pressure trace.

Heart rate

HR increased after induction of anaesthesia and increased again after airway instrumentation (Fig. 1). There were no differences between groups in the mean peak increase in heart rate, (26.6% (2.8) in group 1, 25.7% (3.4) in group 2) or in the mean time to peak increase after instrumentation, (87.0 s (13.5), group 1; 75.3 s (12.5), group 2). At T +0.5, HR was unchanged from T = 0 in group 1 and had increased 8.6% (3.9) in group 2. The increases at T +1 were similar in the two groups (12.4% (3.6) and 14.9% (3.9)). Decreases in HR of > 10% occurred in seven patients in group 1 at a mean time of 22.8 s (2.1) and in two patients in group 2 ($p < 0.001$), at a mean time of 18.7 s (1.9).

Mean HR remained elevated after instrumentation until T +3 in group 1, but began to decrease after T +1 in group 2; there was a significant difference between the groups at T +2 and T +3 (Fig. 1).

Arterial pressure

Systolic arterial pressure (SAP) increased significantly in group 1 at T +0.5 and T +1, but changes in group 2 did not reach significance (Fig. 2). Between-group comparisons were significant at T +0.5. The maximum mean increases (from T = 0) in SAP were 51.3% in group 1 and 22.9% in group 2 ($p < 0.05$) occurring at mean times of 38.8 s and 44.2 s respectively.

Diastolic arterial pressure (DAP), compared with T = 0, increased significantly in group 1 at T +0.5 and T +1; changes in group 2 did not reach significance (Fig. 3). The maximum mean increases in DAP at T +0.5 were 53.2% (4.9) in group 1 and 27.7% (3.8) in group 2.

Table 1. Patient characteristics. Values are expressed as mean (range).

	Group 1	Group 2
Number	19	18
Age; years	31.1 (26–38)	30.4 (26–35)
Weight; kg	57.8 (45–72)	60.2 (50–72)

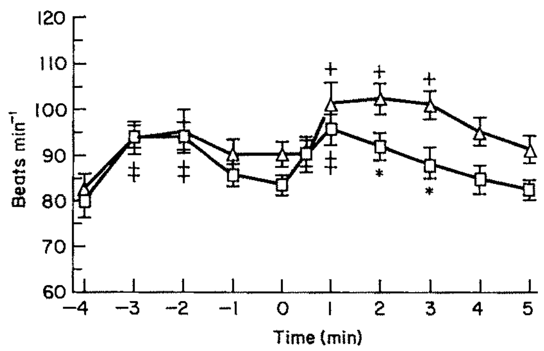

Fig. 1. Heart rate expressed as mean (SEM). Differences where $p < 0.05$ are illustrated as follows: * = between groups at that time; + = within group 1 compared to T = 0; ‡ = within group 2 compared to T = 0. △, tracheal intubation group; □, LMA group.

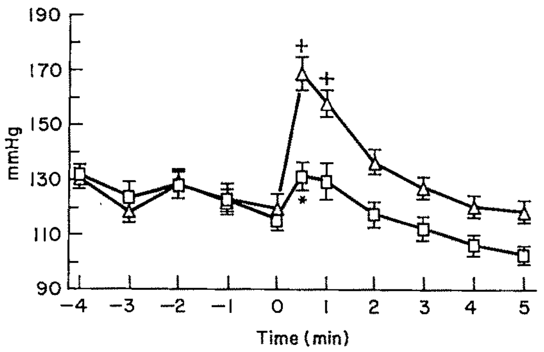

Fig. 2. Systolic arterial pressure expressed as mean (SEM). Differences where $p < 0.05$ are illustrated as follows; * = between groups at that time; + = within group 1 compared to T = 0. △, tracheal intubation group; □, LMA group.

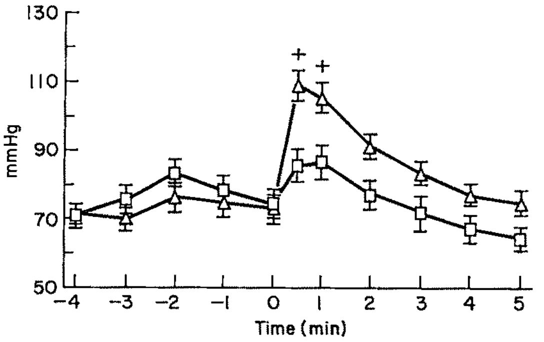

Fig. 3. Diastolic arterial pressure; mean (SEM). + = $p < 0.05$ within group 1 compared to T = 0. △, tracheal intubation group; □, LMA group.

Discussion

Insertion of the LMA produced a small but not significant increase in both systolic and diastolic arterial pressure. However this increase was considerably less, and significantly so, in comparison with that associated with laryngoscopy and tracheal intubation.

The Finapres uses a finger cuff, the pressure of which follows digital artery pressure by using a photoplethysmograph to determine when flow has ceased, and it provides the advantages of a continuous monitor. The technique is well described elsewhere [7]. We would consider the percentage increases observed to represent a significant clinical difference, because the Finapres follows rapid changes in arterial pressure and has been shown to correlate well with simultaneous invasive measures [8–10]. Whilst not providing accurate between-patient measurement [11], within-patient variability is acceptable. The Finapres is known to vary in its reading of mean arterial pressure by as much as 20 mmHg for up to 5% of the time [12] but the postinstrumentation difference in SAP of approximately 40 mmHg in this study suggests that this was a real difference.

Braude and colleagues found no significant difference in pressor response after insertion of a LMA and conventional tracheal intubaton [4]. This may be a reflection of the longer time from induction to intubation or the use of intermittent arterial pressure measurement which failed to detect transient extremes of change.

The smaller cardiovascular response to LMA insertion compared with tracheal intubation presumably reflects a smaller degree of total afferent stimulation rather than avoidance of tracheal stimulation. This effect of a nonspecific pharyngeal stimulation was also demonstrated by Hickey and colleagues [5] who found that insertion of the LMA produced a significant increase in arterial pressure similar to that caused by insertion of a Guedel airway alone.

After a similar increase in HR from T = 0 to T = 1 in both groups, HR remained elevated until T +3 only in the intubation group, suggesting a continued effect caused by the tracheal tube. Shribman and colleagues [13] observed similar increases in arterial pressure after laryngoscopy with and without intubation, but that only intubation was associated with increases in heart rate. They postulated that whereas laryngoscopy produced balanced stimulation of vagal and cardiac accelerator fibres, intubation may have produced less vagal stimulation. It is interesting to note that in the present study, a significantly greater number of patients in the laryngoscopy group had a transient decrease in HR at about the end of laryngoscopy. This may have been caused by a vagal stimulant effect of laryngoscopy which was not present with LMA insertion.

In conclusion, we have found that there was an attenuated cardiovascular response to insertion of the LMA compared with tracheal intubation. The use of the LMA may be useful therefore in situations where the pressor response to intubation should be avoided, e.g. during induction of anaesthesia in the hypertensive patient, and in the less controlled situation of an unexpected difficult airway.

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The relationship between the concentration of temazepam in cerebrospinal fluid and sedation in man

G. A. OSBORNE, N. R. BADCOCK, P. M. McGRATH, W. J. RUSSELL AND D. B. FREWIN

Summary

Twenty-six patients received oral temazepam and subsequently spinal anaesthesia. Blood and lumbar cerebrospinal fluid temazepam levels were measured together with the degree of sedation. The plasma and cerebrospinal fluid concentrations correlated well with the temazepam dose but even better with the weight standardised dose ($r = 0.65$, $p = 0.0003$ and $r = 0.75$, $p = 0.00001$ respectively). Both the plasma and cerebrospinal fluid concentrations of temazepam were correlated with the patient's sedation ($r = 0.42$ $p = 0.037$, and $r = 0.46$ $p = 0.021$ respectively), but neither was strong. Thus, although the drug concentration at the receptor may be a major factor in producing sedation, others factors, possibly the receptor population or their responsiveness, are also important contributors.

Key words

Hypnotics, benzodiazepines; temazepam.
Pharmacokinetics; distribution.

Benzodiazepines are well recognised for their variable dose response and several studies have examined the relationship between plasma level and effect. Bradshaw *et al.* reported a modest correlation between plasma concentration and the clinical effect of lorazepam [1], while another study on temazepam from the same group in 1989, claimed a good relationship between these two parameters [2]. However, in a recent review Dingemanse *et al.* stated that 'data on concentration–effect relationships of CNS active drugs are quite limited' [3].

The physicochemical properties of benzodiazepines are suitable for studying dose–effect relationships and examining variations caused by pharmacokinetic and pharmacodynamic effects. In particular, benzodiazepines with appropriate pKa values and lipid solubilities can penetrate rapidly into the central nervous system (CNS) and reach a rapid equilibrium between blood and all regions of the CNS. The normal protein level in cerebrospinal fluid (CSF) is only about 0.010 $g.100\,ml^{-1}$ i.e. about 1000 times less than in blood, so CSF matches closely the unbound plasma level. Animal studies with diazepam [4] and clonazepam [5] have shown that CSF and blood can reach a rapid equilibrium and give a close correlation between free (unbound) drug concentrations in blood and the CSF level. We have recently shown a good correlation ($r = 0.81$) between the measured fraction of unbound temazepam in plasma and the level of temazepam in CSF in 13 human subjects administered temazepam 20 mg, 75 to 240 min before venous blood and lumbar CSF sampling [6]. Therefore, the concentration of benzodiazepines in the CSF should be a good measure of the concentration to which the neurones within the CNS are exposed, and measurement of the CSF drug concentration should give an estimate of the concentration/effect relationship.

To explore this relationship, we have studied patients undergoing a lumbar puncture for spinal anaesthesia. The lumbar CSF temazepam levels after oral dosing have been taken to represent the 'biophase' drug concentrations to which the CNS benzodiazepine receptors are exposed, and used to evaluate the drug concentration–effect relationship, independent of pharmacokinetic variation.

Temazepam (3-Hydroxydiazepam) is a commonly pre-

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scribed premedicant for spinal anaesthesia as it has a rapid onset of action and a reasonably short elimination half-life of about 8.7 h in the older age group [7]. These favourable pharmacokinetic properties are associated with good anxiolysis and sedation during anaesthesia and surgery. In this study, drug effect was measured in terms of the degree of sedation.

Materials and methods

Subjects

Twenty-six males scheduled to undergo urological surgery under spinal anaesthesia were premedicated with oral temazepam. The study had the approval of the ethics committee of the Royal Adelaide Hospital and informed consent was obtained from each patient. Each patient received a single dose which varied from 10 to 40 mg. Drug administration occurred 1 to 4 h before arrival in the anaesthetic room. No other premedication was prescribed. Subjects who had CNS disease such as a history of a previous cerebrovascular accident or who were receiving CNS active drugs such as anticonvulsants or regular night sedation were not studied.

Upon arrival, the degree of sedation was assessed using a six level scale (Table 1). An intravenous cannula was then inserted into a forearm vein and 5 ml of venous blood were taken and placed in a tube containing lithium heparin for temazepam assay. The patient was positioned in flexion and a spinal needle was inserted. One to two ml of CSF were removed immediately before injection of the spinal anaesthetic. For all patients, the spinal fluid was free of visible blood and the CSF sample was taken within 10–20 min of the venous blood sample. The blood was centrifuged within 0.5 h of collection, and the separated plasma and CSF was protected from light and stored at −20°C until assayed.

Assay methodology

Plasma and CSF temazepam concentrations were measured in duplicate using capillary gas chromatography. This method has been described in a previous paper [6]. The response of the system used was linear from 3–3000 nmol.l^{-1} with a lower limit of detection of 2 nmol.l^{-1}. The between-run coefficient of variation was 4.2% at a concentration of 700 nmol.l^{-1}.

Statistics

Analysis was performed using parametric testing for interval data such as blood levels and adjusted body dose, and nonparametric statistics for correlations with the ordinal data. The correlation between CSF drug concentration and the level of sedation was assessed by a Spearman's nonparametric correlation with replication correction.

Table 1. Guideline to sedation score.

1. Alert.
2. Claims to be slightly drowsy but is not obviously so.
3. Drowsy, but rouses and answers questions.
4. Very drowsy, rouses when spoken to but does not converse.
5. Asleep, responds to mildly painful stimuli, opens eyes.
6. Asleep, no response to mildly painful stimuli.

Results

Group data

The mean age of the 26 patients was 69.7 years (SD 8.4) with a range of 51 to 88 years. Their mean weight was 76.4 kg (SD 7.5) with a range of 65 to 95 kg. The mean time between oral premedication and the initial venous blood sample was 137 mins (SD 54) with a range of 70 to 250 min.

Pharmacokinetic data

The mean dose adjusted for body weight was 0.339 mg.kg^{-1} (SD 0.099) with a range of 0.123 to 0.597 mg.kg^{-1}. The mean plasma level of temazepam was 1284 nmol.l^{-1} (SD 1036) with a range of 296 to 5795 nmol.l^{-1}. The relationship between the dose and plasma level was only moderate ($r = 0.48$, $p = 0.014$) but improved when the dose was adjusted for body weight, Figure 1 ($r = 0.65$ $p = 0.00034$). The mean CSF drug concentration was 68.5 nmol.l^{-1} (SD 38.8) with a range of 18 to 217 nmol.l^{-1}. The relationship between the temazepam dose and the CSF level was fair ($r = 0.59$ $p = 0.002$) and improved when adjusted for body weight ($r = 0.75$ $p = 0.00001$), Figure 2. The mean CSF/plasma ratio was 6.16% (SD 2.42%) and varied from 3.0% to 12.5%. These values were similar to those previously observed [6].

Pharmacodynamic data

The patient sedation scores ranged from 1 (alert) to 4 (very drowsy, rouses when spoken to but does not converse). No patient reached a sedation score of 5 or 6. There was a modest correlation between the plasma temazepam level and the degree of sedation, $r = 0.42$, $p = 0.037$ (Spearman), Figure 3. However, the relationship between the CSF concentration and the degree of sedation was only slightly better $r = 0.46$, $p = 0.021$, Figure 4.

Discussion

This study has provided some interesting data on both the kinetics and dynamics of temazepam in man. The vari-

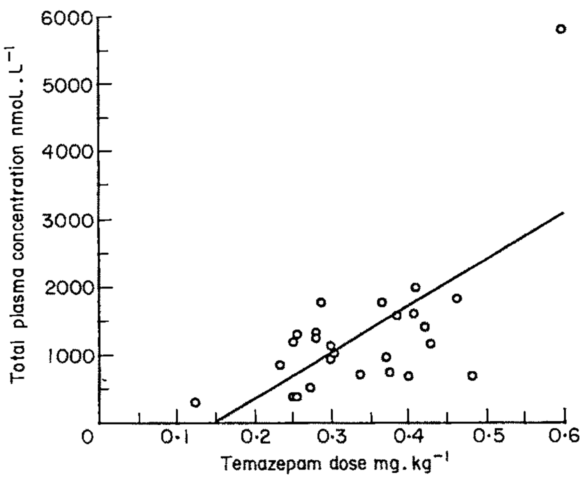

Fig. 1. Relationship between temazepam dose in mg.kg^{-1} and total plasma drug concentration. This relationship has a good fit ($r = 0.65$, $p = 0.00034$) with the linear equation; total plasma concentration. $= 6825 \times$ dose mg.kg^{-1} — 1029.

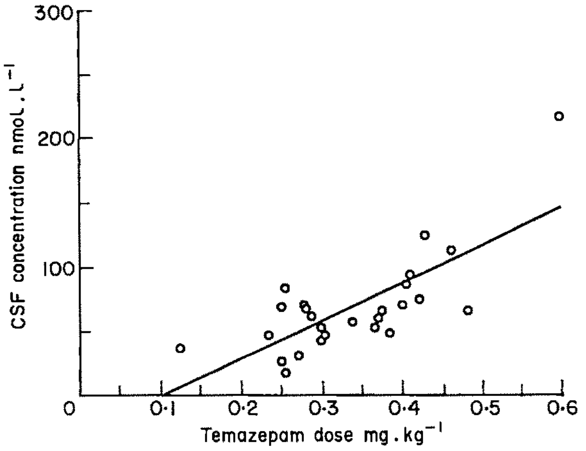

Fig. 2. Relationship between the weight standardised temazepam dose and CSF drug concentration. The relationship has a good fit ($r = 0.75$, $p = 0.00001$) with the linear equation; CSF concentration. = 293.7 × dose mg.kg^{-1} — 31.00.

ability of the CSF/plasma temazepam concentration ratio is not surprising, as significant fluctuation in this ratio has been observed for this and other benzodiazepines in the past [5, 8], although little information is available for humans taking temazepam.

The mean CSF/plasma concentration ratio showed a fourfold variation (with its implied equivalent alteration in the proportion of free plasma drug level). This is presumably caused by differences in drug binding to plasma proteins in each patient. On theoretical grounds this should have a major impact on drug effect. Thus, for a given dose, an alteration in plasma protein binding could be expected to cause an inverse change in the free drug level and therefore the clinical effect. The change in binding could be expected to alter the plasma concentration–effect relationships. However, variation in plasma protein binding should not affect free drug concentration–effect relationships.

The present study uses the CSF level of temazepam as an index of the free drug level, which should represent the concentration at the receptor. However, there is little improvement in the correlation between the CSF concentration and the sedative effect of the drug compared with its plasma concentration and effect. It is surprising that even the CSF concentration is only a modest predictor of the sedative effect. With the correlation of 0.46 between CSF concentration and sedation, much of the sedative effect remains unaccounted for. Thus, although the concentration of temazepam may set the level of sedation in an individual, as a group, the sedative effect in these subjects is not tightly coupled to the CSF temazepam concentration. A large proportion of the effect is being influenced by other factors.

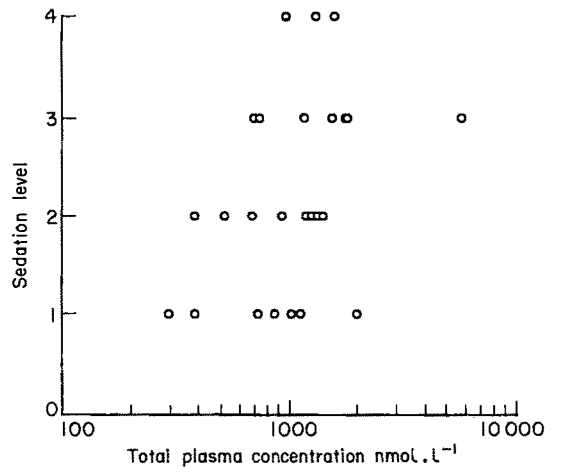

Fig. 3. Relationship between the total plasma temazepam concentration and sedation. Overall there is a moderate positive correlation ($r = 0.42$, $p = 0.037$ Spearman).

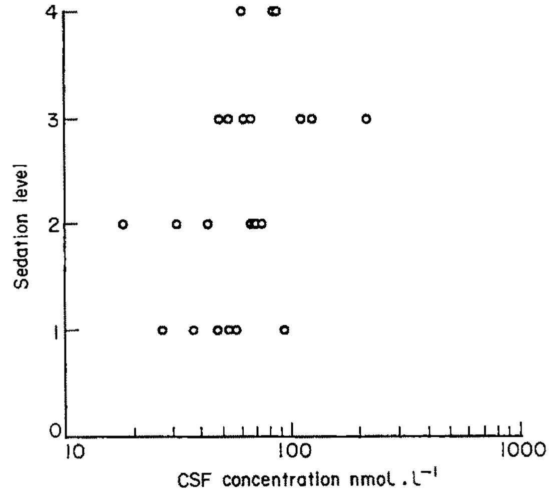

Fig. 4. Relationship between the CSF temazepam concentration and sedation. Overall there is a moderate positive correlation ($r = 0.46$, $p = 0.021$ Spearman).

Factors which could alter the response of temazepam are, differences in the population of CNS benzodiazepine receptors or differences in receptor sensitivity between patients. Other factors which might reduce the CSF concentration–effect correlation include experimental errors in drug assay or blood and CSF sampling, limitations in the precision of the sedation measurements, a difference in CSF temazepam concentrations between the lumbar and cerebral regions, variation in CSF protein, CSF pH values, or receptor upregulation/downregulation caused by chronic use of other drugs such as alcohol. None of these possibilities seems to be substantial enough to explain the difference. Indeed, only the sedation estimate seems susceptible to significant measurement error, and variability from the imprecision of the sedative measurement must be acknowledged. However, although subjective and other observer variability may explain a difference between one level and an adjacent level, the overlap of CSF drug concentrations between level 1 and levels 3 and 4 sedation and that between level 2 and level 4 sedation is harder to explain in this way. More objective measurements of CNS impairment such as critical flicker fusion could be used to improve reliability, but the clinical effect sought is sedation, which is why in this study it was chosen as the effect parameter.

The only modest correlation between CSF drug concentration and effect is a significant observation. This is in conflict with the simple notion of the amount of drug at the receptor being constant for a given effect. It suggests that there may be an important element in the variability of benzodiazepine action which is a receptor or cellular response phenomenon. In the past, variability in effect has been focused on variability in absorption, first-pass metabolism, protein binding, and/or CNS penetration. However, the measurement of temazepam in the CSF goes beyond the point at which conventional bioavailability and other pharmacokinetic factors can influence the response.

The use of CSF sampling (and the examination of CSF drug level/effect relationship) as we have employed, should detect alterations in receptor numbers or responsiveness in patients. This technique should be able to detect alterations either as a consequence of genetic factors or of acquired factors such as previous chronic benzodiazepine exposure. A decrease in receptor numbers or sensitivity should be revealed as a flatter slope on the concentration/sedation curve. There is some evidence in animal studies that chronic treatment with benzodiazepines is associated with decreased receptor binding [9]. However, there is no evidence as yet for this phenomenon in man.

We feel that much of the variation we have seen in CSF drug concentration–effect is likely to be due to true pharmacodynamic variability. The CSF drug concentration–effect model that we have used should be further exploited in studies on receptor–agonist relationships for other drugs with CNS actions to see whether the drug concentration at the receptor causes only a minor influence as it seems to do with temazepam.

Acknowledgments

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Anaesthesia, 1992, Volume 47, pages 307–310

Peroperative arterial hypoxaemia. The interaction between intrapulmonary shunt and cardiac output

A computer model

J. L. WESTBROOK AND M. K. SYKES

Summary

A computer model of respiratory physiology was used to investigate the interaction between cardiac output and intrapulmonary shunting during anaesthesia. Significant degrees of arterial desaturation were demonstrated as the cardiac output was reduced. We suggest that volume expansion may correct some episodes of desaturation observed during anaesthesia.

Key words

Heart; cardiac output.
Lung; shunt.

Recent studies using pulse oximetry have revealed that there is a surprisingly high incidence of arterial desaturation during the peri-operative period [1]. It is known that patients who undergo major abdominal surgery develop an intrapulmonary shunt ($\dot{Q}s/\dot{Q}t$) of 5–20% [2] and it has recently been shown that this is due to the development of compression collapse in the dependent areas of the lungs. The collapsed areas are seen on computerised axial tomographic (CAT) scan of 90% of patients within a few minutes of the induction of anaesthesia and persist into the postoperative period. The opacities are seen in patients anaesthetised with intravenous or inhalational techniques, either with spontaneous or controlled ventilation, but not in patients in whom anaesthesia is induced with ketamine. However, the use of muscle relaxants in patients who have received ketamine does induce collapse and also aggravates collapse already seen in spontaneously breathing subjects [3].

Normally, the effects of the increased shunt on arterial oxygenation are minimised by the administration of 30–40% oxygen. Although this usually maintains pulse oximeter readings (Spo_2) of 97% or more during anaesthesia, episodes of arterial desaturation still occur. In patients who undergo major abdominal surgery, the desaturation is often due to increased pulmonary collapse secondary to obesity, intra-abdominal manipulation or the presence of packs, particularly when pressure is placed on the diaphragm. Hypoxaemia from this cause can be reversed by hyperinflation of the lungs or the addition of positive end-expiratory pressure (PEEP). However, episodes of desaturation are seen also when there is no reason to believe that there is any change in the gas exchange efficiency of the lung. These episodes are often associated with episodes of hypovolaemia, particularly associated with arterial hypotension, and they usually resolve when blood loss is replaced. In order to quantify the potential magnitude of the changes of Spo_2 due to this cause we have examined the relationship between inspired oxygen concentration, intrapulmonary shunt, cardiac output and arterial saturation on the Macpuf computer model of the respiratory system.

Methods

The standard 70 kg subject was modelled on the Macpuf respiratory program [4]. The computer model was subjected to mechanical ventilation with an inspired oxygen concentration of 33% to achieve a physiological carbon dioxide tension ($Paco_2$) of 5.2 kPa using a minute volume 6.1 $l.min^{-1}$ with a respiratory quotient of approximately 0.8. An intrapulmonary shunt ranging from 5% to 20% of the total cardiac output was introduced and the program was run until a steady state had been achieved. The cardiac output was then reduced in 10% decrements to 40% of normal. At each stage, all respiratory and cardiovascular parameters were recorded for subsequent study. An example of the results obtained is shown (Table 1).

These simulations were repeated with high and low

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minute volumes to achieve hypocapnia and hypercapnia in order to study possible effects of changes in carbon dioxide tension.

Further experiments were performed using the same standard computer model but with the addition of PEEP of 10 cmH_2O to the breathing system.

Results

Increased intrapulmonary shunt predictably produced a decrease in arterial oxygen saturation (Fig. 1). At each level of shunt, stepwise reductions in cardiac output from 90% to 40% of baseline produced further decreases in arterial saturation. In the patient model with a 5% shunt (6.4% total venous admixture) arterial oxygen tension (Pa_{O_2}) decreased from 15.4 kPa to 11.5 kPa; with a 20% shunt (21.4% total venous admixture) the decrease was from 9.1 kPa to 7.0 kPa. As expected, mixed venous oxygen tension decreased progressively with cardiac output despite a reduction in oxygen consumption (Table 2).

In the computer model at normocapnia, Pa_{CO_2} remained between 4.7 and 5.1 kPa, despite a small decrease in carbon dioxide production of approximately 12% due to the reduction in cardiac output from 100% to 40%. In the hypocapnic model with a Pa_{CO_2} of 3.3 kPa, the degree of desaturation was similar to that which occurred in the normocapnic model, although the Pa_{O_2} was slightly lower. In the hypercapnic model (Pa_{CO_2} 6.2 kPa) the decrease in Pa_{O_2} was the same as in the normocapnic simulation, but the saturation was 1% lower because of the rightward shift in the oxygen dissociation curve due to the high Pa_{CO_2} and low pH (Fig. 2).

An experiment conducted using the same conditions as the standard patient model but with 10 cmH_2O of PEEP showed a lower Pa_{O_2} and arterial saturation (Fig. 3). This appeared to be due to a 25% reduction in cardiac output and a resulting decrease in mixed venous oxygen tension caused by PEEP.

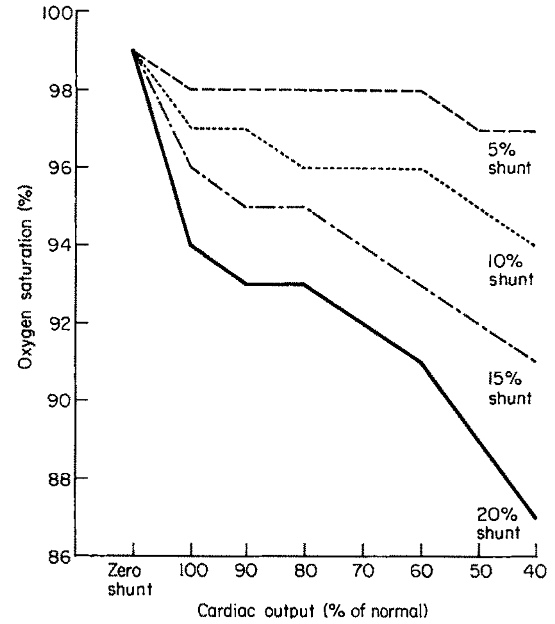

Fig. 1. Change in arterial oxygen saturation as shunt is introduced and then cardiac output decreased.

Discussion

This study was prompted by the observation that episodes of arterial desaturation occurred without apparent cause during anaesthesia for major abdominal procedures. On some occasions the desaturation was reversed readily by the application of several large tidal volume breaths and so appeared to be due to increased alveolar collapse. On other occasions this manoeuvre was ineffective but the saturation was restored to normal levels by the infusion of a plasma expander.

The arterial saturation depends on the Pa_{O_2} and the position of the oxygen dissociation curve. Pa_{O_2} depends in

Table 1. Example of initial readings with subject stabilised on FI_{O_2} 0.30 and 5% shunt (venous admixture 6.4%) with normal cardiac output.

	Partial pressures		Contents (ml%)		Amounts (ml)			
	O_2	CO_2	O_2 (STPD)	CO_2	O_2 (STPD)	CO_2	pH	HCO_3^-
Arterial	15.4	5.2	19.8	46.9	198	469	7.404	23.6
Alveolar/lung	22.5	5.1	(Sat = 98%)		580	141		
Pulmonary capillary	22.5	5.1	20.2	46.6				
Brain/CSF	3.7	7.1	9.7	56.9	18	681	7.330	22.7
Tissue/ECF	5.4	6.0	14.6	51.1	180	13339	7.375	
Mixed venous	5.4	6.0	14.7	51.0	441	1530	7.375	25.3

O_2 uptake = 250 ml.min^{-1}; CO_2 output = 202 ml.min ^{1}(STPD); RQ = 0.81; respiration rate = 10 min^{-1}; total ventilation = 6.1 l.min^{-1}; alveolar ventilation = 4.6 l.min^{-1}(BTPS); deadspace = 152 ml; tidal volume = 610 ml(BTPS); cardiac output = 4.9 l.min^{-1}; V_D/V_T ratio = 0.25; plasma lactate = 1.0 mmol.l^{-1}; venous admixture = 6.4%; cerebral blood flow = 49 ml.100 g^{-1}. min^{-1}. STPD, standard pressure and pressure dry; BTPS, barometric temperature and pressure saturated; ECF, extracellular fluid.

Table 2. Changes in oxygen consumption (V_{O_2}) and arteriovenous oxygen content difference (A–V_{O_2}) with decrease in cardiac output from 100% to 40% of normal for shunt of 15%.

Cardic output (%)	100	90	80	70	60	50	40
Oxygen							
consumption; ml.min^{-1}	252	247	245	242	240	235	226
A–V_{O_2}; ml %	5.0	5.4	6.0	6.8	7.8	9.0	10.7

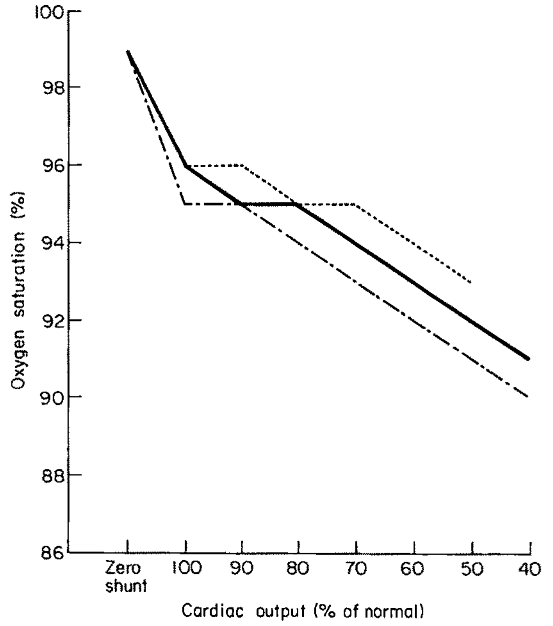

Fig. 2. Influence of carbon dioxide tension on change in arterial oxygen saturation as cardiac output is decreased. (……., low $P\mathrm{aco}_2$; ———, normal $P\mathrm{aco}_2$; —·—·, high $P\mathrm{aco}_2$.)

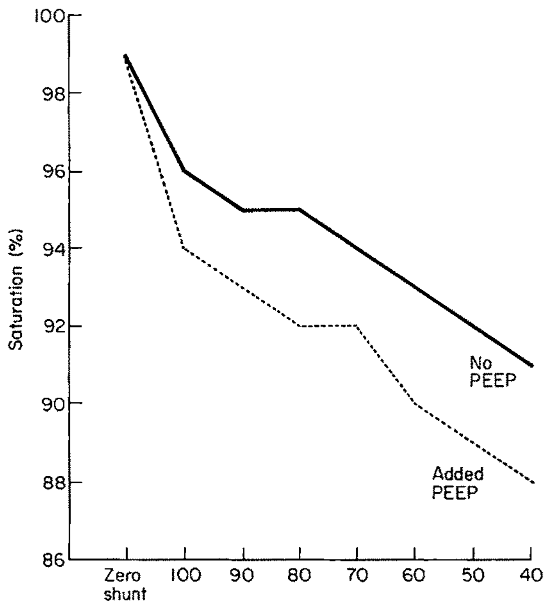

Fig. 3. Influence of positive end-expiratory pressure (PEEP) on change in arterial oxygen saturation as cardiac output is decreased.

turn on the alveolar–arterial $P\mathrm{o}_2$ difference (A–a $P\mathrm{o}_2$). The alveolar oxygen tension is determined by the inspired oxygen tension, the alveolar ventilation and the respiratory exchange ratio. When anaesthesia is stable, these factors should be relatively constant and so should not affect the $S\mathrm{po}_2$.

The significant increase in the A–a $P\mathrm{o}_2$ that has been demonstrated during anaesthesia is largely due to changes in 'physiological shunting'. Of the three factors which contribute to this shunt, one, the anatomical right-to-left shunt from the Thebesian veins, bronchial circulation and other pulmonary arteriovenous anastomoses, is small and fixed. The remaining two factors (blood flow through areas with low ventilation/perfusion ratio and through collapsed areas of lung) may be increased during anaesthesia.

Although it has been known for many years that anaesthesia results in an increase in right-to-left shunt [2], it has been demonstrated only recently that the shunt is produced by the development of areas of compression collapse in the dependent lung zones [3]. These changes occur within a few minutes of induction, are present in approximately 95% of patients studied and persist into the postoperative period. The magnitude of the increase in shunt correlates with the size of the opacities on CAT scan, is greater in short, fat subjects than in tall, thin subjects and is greater during controlled than spontaneous ventilation. The collapsed areas re-expand when the patient is turned so that they are in the nondependent position, but collapsed areas then appear in the lung zones now made dependent.

The arterial oxygen saturation depends on the oxygen content of the blood leaving the ventilated parts of the lung, the proportion of blood perfusing collapsed areas of lung and the saturation of the mixed venous blood flowing through the shunt. During anaesthesia, the inspired and alveolar oxygen tensions are usually increased to levels which ensure full saturation of blood leaving ventilated alveoli, including those with low ventilation/perfusion ratios. The proportion of blood which flows through the shunt depends on the relative areas of ventilated and collapsed lung, the pulmonary vascular pressures and the blood gas tensions of the mixed venous blood perfusing the collapsed alveoli.

The perfusion of the nondependent ventilated areas of lung depends on the relationship between alveolar and pulmonary vascular pressures [5]. If cardiac output is reduced, there is a reduction in pulmonary artery pressure so that flow through the oxygenated areas of lung decreases. Although there may also be a decrease in driving pressure across collapsed dependent zones it is likely that the relative decrease in flow is less because of the decrease in both pulmonary artery and left atrial pressures. Hence the proportion of blood flowing through the shunt increases, even though there is little change in the actual flow through this area of lung. Similar effects are produced if mean alveolar pressure is increased by the use of high and/or prolonged inspiratory pressures, or the application of PEEP. In both circumstances, the decrease in mixed venous saturation resulting from the decrease in cardiac output augments the effects of increased shunt in decreasing arterial saturation.

The blood flow through the dependent, collapsed areas of lung depends on the driving pressure across the collapsed areas and the resistance of the vessels in these areas. Absorption atelectasis in the open-chest experimental model results in a 30–60% decrease in blood flow, but the reduction may be less when the chest is closed and the collapsed area is exposed to a greater subatmospheric pleural pressure [6]. The decrease in flow in collapsed lung is due principally to hypoxic pulmonary vasoconstriction augmented by the higher $P\mathrm{co}_2$ tension in mixed venous blood [7], though mechanical and neurohumoral factors may have a small effect [8]. Hypoxic vasoconstriction may be rendered less effective if intravascular pressures are increased [9] and may be decreased by anaesthetics, bronchodilators, vasodilators and inotropic drugs [10]. However, it is unlikely that inhalational anaesthetics exert any significant effect on hypoxic vasoconstriction at concentrations used in modern anaesthetic practice [11].

Obese patients often develop progressive arterial desaturation during anaesthesia and a decrease in Sp_{O_2} is often observed when there are surgical manipulations under the diaphragm or abdominal packs are inserted. In such patients, the application of three to four deep breaths often results in a transient decrease in Sp_{O_2} of 1–3% followed by an increase to Sp_{O_2} values which existed before surgical manipulation. The transient decrease in Sp_{O_2} is due probably to the mechanisms discussed above while the subsequent increase in Sp_{O_2} indicates probably that re-expansion has taken place. However, this manoeuvre is unlikely to affect that part of the compression collapse which is associated with the reduction of functional residual capacity resulting from induction of anaesthesia.

The Macpuf computer model used in this study is not programmed to allow for all physiological changes that may occur during induction and maintenance of anaesthesia. In particular, the physiological changes described above of alveolar collapse/atelectasis and re-expansion are not reproduced. However, it does allow for manipulations of many respiratory and cardiovascular parameters that might vary in a ventilated patient.

It was the aim of this study to quantify the degree of hypoxaemia which may be attributed to hypovolaemia and reduced cardiac output with a view to possible future experimental work to investigate the phenomenon. To this end we have used the program to manipulate the parameters described and then simply introduced a fixed intrapulmonary shunt to represent shunting which occurs during anaesthesia (5–20%). The exact composite parts of this shunt (the proportion attributable to $\dot{V}/\dot{Q}$ mismatching compared to that due to flow through unventilated areas and other effects of anaesthesia) are beyond the scope of the program. It is intended that by running the model until steady-state is achieved before introducing the shunt and reductions in cardiac output, the effects of changing from spontaneous ventilation on air to IPPV with an Fi_{O_2} of 0.3 are excluded from the observed results.

A reduction of flow to the nondependent ventilated areas of the lung and a decrease in mixed venous oxygen saturation are obviously major causes of hypoxaemia in severe hypovolaemic shock. However, these computer simulations and our clinical experience suggest that it may account for episodes of decreased Sp_{O_2} during major surgery. General anaesthesia with controlled ventilation often results in a 20–30% reduction of cardiac output, and more profound decreases may occur without marked decreases in arterial pressure, particularly if the patient is dehydrated. Thus, we suggest that consideration should be given to plasma volume expansion when the Sp_{O_2} decreases in the absence of any other cause.

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Anaesthesia, 1992, Volume 47, pages 311–315

A nasal CPAP system

Description and comparison with facemask CPAP

A. N. THOMAS, J. P. RYAN, B. DORAN AND B. J. POLLARD

Summary

Nasopharyngeal pressures were compared in eight subjects breathing through either a nasal CPAP system or facemask CPAP system at a fresh gas flow of 50, 75 and 100 $l.min^{-1}$. *During nose breathing there was no significant difference in nasopharyngeal pressure between the two systems. During mouth breathing pressures were significantly lower with nasal CPAP. During nose breathing at 75* $l.min^{-1}$ *the mean inspiratory and expiratory pressures in* cmH_2O *(SD) were 3.4 (0.68) and 5.9 (0.55) for nasal CPAP and 3.3 (0.71) and 6.3 (0.73) for facemask CPAP. The respective pressures during mouth breathing were 0.3 (0.73) and 2.9 (1.74) for nasal CPAP and 3.9 (0.73) and 5.8 (0.82) for facemask CPAP.*

Key words

Equipment; CPAP, nasal CPAP.

The use of nasal continuous positive airway pressure (N-CPAP) in the treatment of the sleep apnoea syndrome is well known [1], as is its use in children [2]. More recently there have been a number of reports on the use of N-CPAP in adults suffering from pulmonary atelectasis secondary to both neurological disease [3] and after cardiac surgery [4]. It has also been used in patients with both pneumocystis [5] and viral pneumonias [6]. When CPAP is required in extubated patients on the Intensive Care Unit it is commonly applied by full facemask. While the efficiency of facemask CPAP is widely accepted [7], the mask itself is often poorly tolerated by patients. In contrast to this, the use of N-CPAP in the sleep apnoea syndrome suggests that it is well tolerated by patients. However, the exact role of N-CPAP in patients with pulmonary pathology who require additional oxygen has not been clearly defined. The aim of this study has been to describe an N-CPAP system that may be used in this group of patients. We have also compared the nasopharyngeal pressures generated by this system with those produced by a conventional facemask CPAP. Measurements were made at fresh gas flows of 50, 75 and 100 $l.min^{-1}$ whilst breathing through the mouth and also breathing through the nose.

Materials and methods

Description of the N-CPAP circuit

The N-CPAP circuit used is illustrated in Figure 1. A 5 cmH_2O CPAP valve (Vital Signs Inc., Totowa, NJ) was positioned approximately 500 mm from the patient connection. Placement nearer the flow generator causes a significant resistance in the system between the patient connection and the CPAP valve and this results in a marked difference between the pressure at the valve and the pressure delivered to the patient. Placement nearer the patient results in increased discomfort due to the weight of the valve. Variations in pressure throughout the system also mean that an accurate measurement of the pressure delivered to the patient can only be made close to the patient-end of the system.

The patient connection was made using Adams pillows

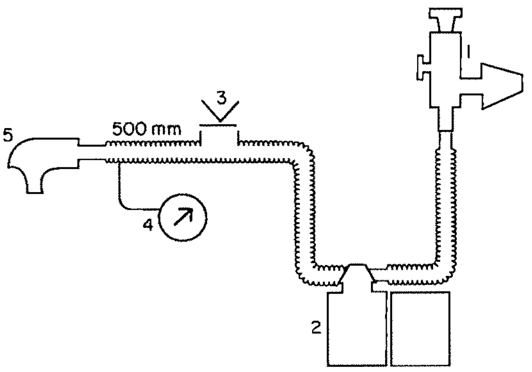

Fig. 1. Nasal CPAP circuit: 1, Downs adjustable flow generator; 2, Concha therm humidifier; 3, CPAP valve; 4, Pressure monitor line; 5, Adams pillows.

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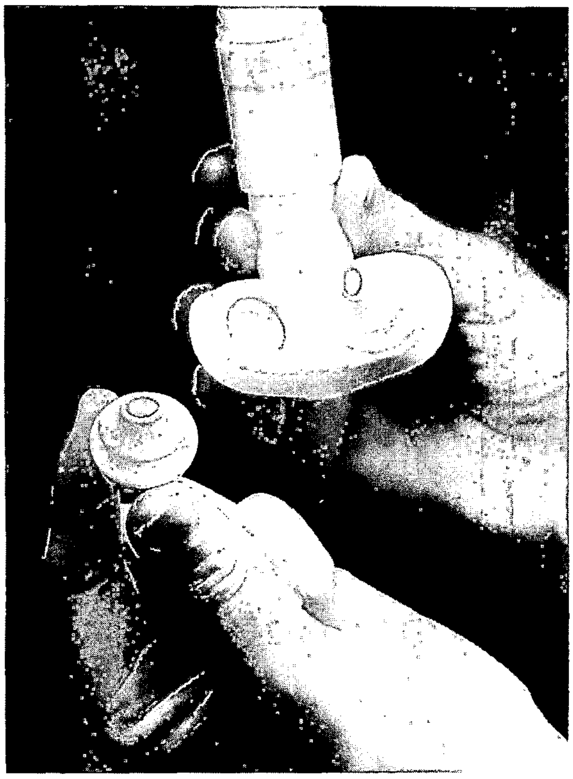

Fig. 2. Adams pillow and holding shell.

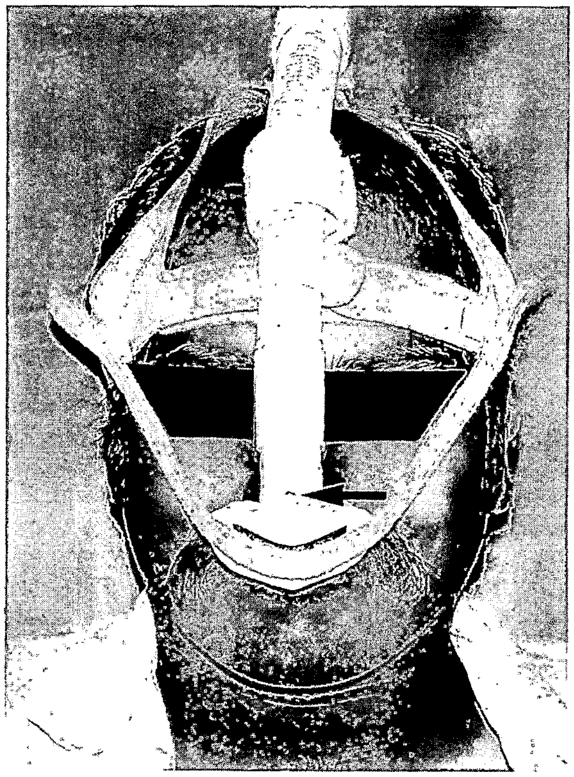

Fig. 3. Correct positioning of adams pillows with headgear assembly.

(Puritan Bennett Corp.) (Fig. 2). These were chosen in preference to the conventional nasal mask in an attempt to improve patient comfort and obtain a more reliable seal around the nares. The pillows are available in three sizes and by the use of the appropriate size we have been able to obtain a reliable seal in all the patients we have studied. The pillows are held in position with the standard headgear assembly provided by the manufacturers (Fig. 3).

Humidification of the inspired gas was considered necessary to avoid drying of the nasal mucosa and was provided using a Concha Therm Humidifier (Kendal UK) We did not, however, make any attempt in this study to measure the humidity of the inspired gas, either within the system or the nasopharynx.

Comparison of nasopharyngeal pressures N-CPAP and facemask CPAP

Eight healthy subjects with no history of recent nasal obstruction were recruited from within the Department of Anaesthesia. In each of these subjects an 8-FG nasogastric tube was placed so that the tip was visible just beyond the soft palate. The tube was then cut at the level of the nares and connected via a manometer line to the pressure transducer of a Mercury Flow Measurement Box (Mercury Electronics). A continuous recording of the measured airway pressure was made using a Gould 2400 four-channel chart recorder. Recordings were made of the nasopharyngeal pressure during normal and deep breathing via both the mouth and nose. The peak inspiratory and expiratory flows were also recorded during both normal breathing and hyperventilation. This was achieved by asking the subjects to breathe through a short piece of flexible ventilator tubing that was connected to a flow transducer (Hamilton Medical, Switzerland), which was in turn connected to the Mercury Flow Measurement Box. The flow transducer was calibrated using a calibration analyser (Timer Instruments) and this calibration was checked before each set of measurements were made. Calibration of the pressure transducer in cmH_2O was achieved using a Checkmate Pneumatic Tester (Bourns Medical, Riverside, CA) and again this calibration was checked before each set of measurements were made. All measurements were made with subjects seated upright at an angle of 90°.

After the baseline readings had been made, half the subjects breathed through the previously described N-CPAP system. The other subjects breathed through a system in which the nasal mask and CPAP valve had been substituted for a facemask (Vital Signs Inc. CPAP mask) with a $5\,cmH_2O$ CPAP valve attached. Using the previously described flow transducer the fresh gas flow through the system was adjusted to give flows of 50, 75 and $100\,l.min^{-1}$. At each of these flows, recordings of nasopharyngeal (NP) pressures were made during quiet respiration and hyperventilation through both the nose and mouth. The recordings of NP pressure were made over at least 5 breaths and the minimum pressures during each inspiration and the maximum pressure during each expiration were measured and their individual means calculated. Examples of the recordings made are shown in Figure 4, which shows a recording made during mouth breathing with the N-CPAP system superimposed on a recording made during nose breathing using the same system. The system pressure just proximal to the patient connection was also measured and analysed in the same way. Measurements were then repeated with the subject breathing through the facemask if N-CPAP had previously been used or N-CPAP if the full facemask had been used.

Comparisons of NP pressures generated at different flows and with the two different types of mask were

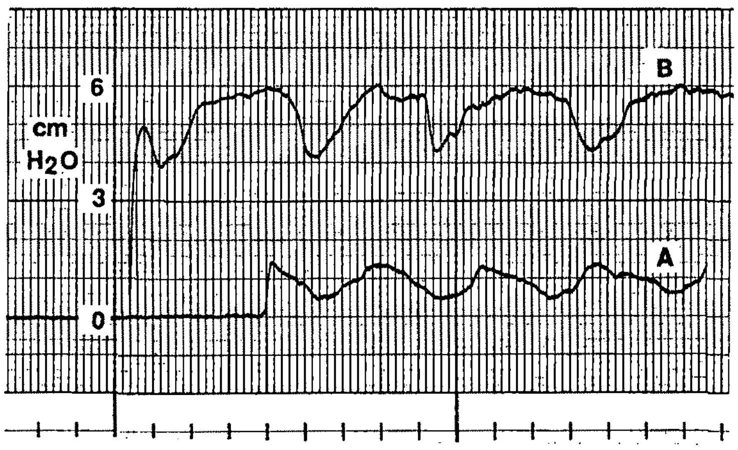

Fig. 4. Nasopharyngeal pressure recording during mouth (A) and nasal (B) breathing.

compared using standard multiple regression methods [8]. Appropriate multiple comparison tests were then used to compare baseline NP pressures with those made during CPAP. Significance was set at the conventional 5% level.

Results

Six of the subjects were male and two female. Their mean age was 32 (SD 4) years, the mean weight was 75 (SD 6.5) kg and the mean height was 174 (SD 9) cm. The mean peak inspiratory flow was 20 (SD 6) $l.min^{-1}$ during quiet breathing. In two subjects the nasopharyngeal (NP) pressures generated during hyperventilation were outside the recording range of the pressure transducer and these subjects were subsequently only studied during normal breathing. The mean peak inspiratory flows for the remaining 6 subjects was 47 (SD 20) $l.min^{-1}$.

The mean minimum inspiratory pressures and mean maximum expiratory pressures generated by the subjects during nasal breathing before CPAP and using the two CPAP circuits are shown in Figure 5. There was no significant difference between the pressures generated by either mask at any of the flows studied, during hyperventilation or normal breathing. The difference between inspiratory and expiratory pressures was significantly greater during hyperventilation when compared to normal respiration.

The mean minimum inspiratory and maximum expiratory NP pressures generated during mouth breathing are shown in Figure 6. Pressures generated during both inspiration and expiration were significantly less during N-CPAP than with facemask CPAP both for normal breathing and hyperventilation at all three flows studied. The peak expiratory pressure generated by N-CPAP was significantly higher than expiratory pressure before CPAP ($p < 0.05$) at all flows. The inspiratory pressure increased with flow and was significantly higher than that recorded

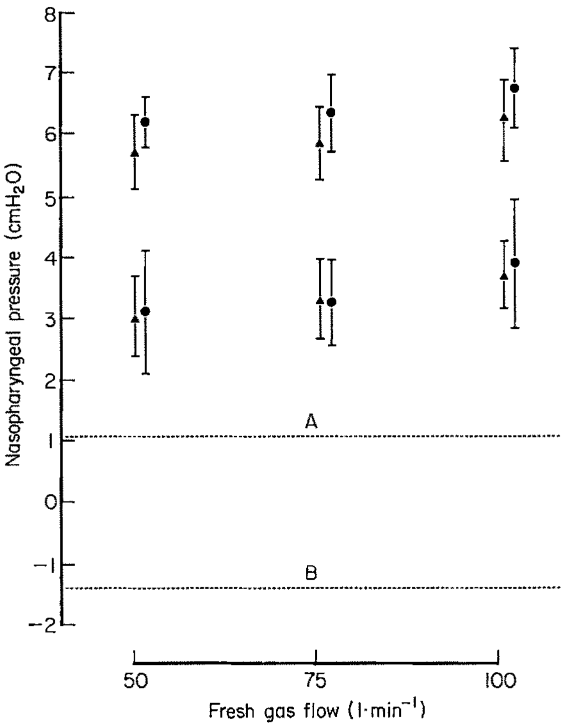

Fig. 5. Nasopharyngeal pressures during nasal breathing using nasal (▲) and facemask (●) CPAP. A, mean expiratory pressure before CPAP; B, mean inspiratory pressure before CPAP.

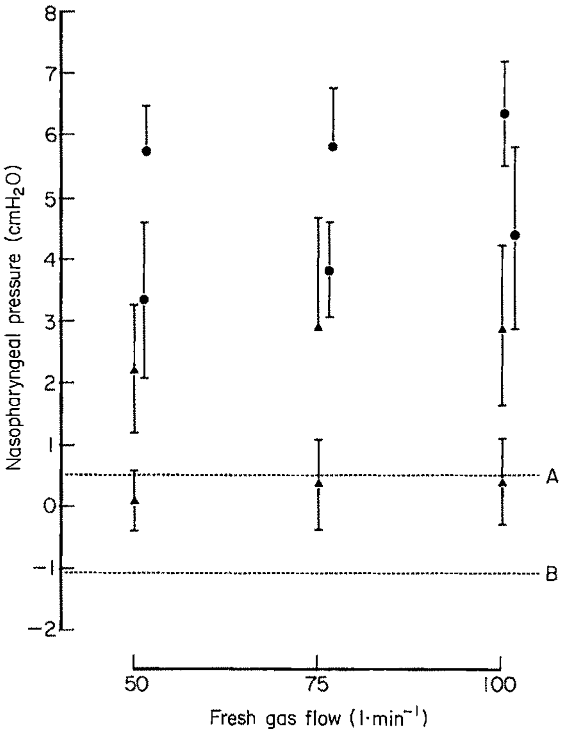

Fig. 6. Nasopharyngeal pressure during mouth breathing using nasal (▲) and facemask (●) CPAP. A, mean expiratory pressure before CPAP; B, mean inspiratory pressure before CPAP.

Table 1. Breathing system pressures during normal mouth and nose breathing.

CPAP	50 l				75 l				100 l			
	N-CPAP		Facemask		N-CPAP		Facemask		N-CPAP		Facemask	
	1	2	1	2	1	2	1	2	1	2	1	2
Inspiration	4.72	3.97	5.09	4.97	4.69	4.13	5.69	5.69	5.09	4.78	6.06	5.91
	(0.82)	(1.31)	(0.40)	(0.49)	(0.35)	(0.67)	(0.37)	(0.46)	(0.38)	(0.54)	(0.4)	(1.10)
Expiration	5.13	4.56	5.69	5.69	5.16	4.53	6.19	6.13	5.53	5.06	6.69	6.88
	(0.71)	(0.98)	(0.29)	(0.35)	(0.35)	(0.56)	(0.56)	(0.58)	(0.51)	(0.42)	(0.61)	(0.63)

1. nose breathing; 2, mouth breathing.

before CPAP at the highest fresh gas flow of 100 l.min^{-1} ($p < 0.05$). In spite of this, inspiratory pressure remained negative during hyperventilation, even at a gas flow of 100 l.min^{-1}.

The pressures recorded in the two systems, just proximal to the subject connection, are shown in Table 1. The pressure in the N-CPAP system was significantly lower than the facemask circuit ($p < 0.05$), and this difference was greater at the higher fresh gas flows. The lower pressure in the N-CPAP circuit was probably caused by an air leak through a hole that is present in the shell that holds the Adams pillows in place (Fig. 3).

Discussion

The delivery of CPAP pressures that are close to the blow-off pressure of the CPAP valve depends on the correct assembly of the system as described in the first part of the study. This assembly is, however, straightforward and the equipment required is inexpensive and readily available. Our experience with the system suggests that it is comparatively well tolerated by patients.

The aim of the second part of this study was to compare the NP pressures generated by the two types of mask. The use of an 8F nasogastric tube to measure nasopharyngeal pressure will have increased the resistance of the nose, so exaggerating the difference between inspiratory and expiratory pressures. This effect will have been equal for both of the masks studied. Measurement of inspiratory and expiratory flows before CPAP probably do not reflect accurately those flows which are generated during CPAP. These measurements do, however, give a rough quantitative guide to the division between 'normal' breathing and hyperventilation and any inaccuracy introduced is again equal in the two masks studied.

The results of our study clearly show that during nose breathing over the range of fresh gas flow studied, the nasopharyngeal pressures generated with N-CPAP did not differ significantly from those produced during full facemask CPAP. During mouth breathing, however, the N-CPAP system generated pressures that were significantly lower than those generated by the facemask system. N-CPAP could only reliably generate spontaneous PEEP at fresh gas flows of 75 and 100 l.min^{-1} and the system was unable consistently to deliver CPAP even at a flow of 100 l.min^{-1}. Increasing the flow above this level to generate CPAP during mouth breathing resulted in a significant increase in both the system and nasopharyngeal pressures during nose breathing and was too uncomfortable to have any useful clinical application.

The relatively poor function of N-CPAP during mouth breathing may limit its role in the treatment of hypoxaemia on the Intensive Care Unit. A further disadvantage of N-CPAP not illustrated in this study is that the subject, by tensing his soft palate, may completely obstruct the flow of gas from the N-CPAP system. N-CPAP is, however, well tolerated by patients and it may therefore find a role in situations where the advantage of CPAP is normally outweighed by the discomfort of a full facemask. Examples of this may include the prevention of episodic obstructive apnoea after opiate administration and as an adjuvant to physiotherapy in the treatment of pulmonary atelectasis after abdominal surgery.

There may be a number of reasons for the apparent discrepancy between the results obtained in this study and previous clinical reports of a beneficial effect of N-CPAP [3–6]. Firstly, in patients with a reduced functional residual capacity, CPAP tends to reduce the work of breathing [9] and these patients may therefore use nasal breathing with N-CPAP in preference to mouth breathing. Secondly, the spontaneous PEEP generated by the mask during mouth breathing may in itself have a beneficial effect [10].

In summary, we would suggest that providing the loss of function during mouth breathing is appreciated, the system that we have described is suitable for use in adult patients who require a period of CPAP.

Acknowledgments

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Nasal CPAP after coronary artery surgery

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Summary

Two groups of 14 patients were compared after coronary artery bypass surgery where the left internal mammary artery had been used as a conduit. One group received nasal continuous positive airway pressure for 1 h, the other group acted as a control. Mean pulmonary shunt fraction was 16.3% before, 12.6% during and 15.7% after continuous positive airways pressure. In the control group the shunt fraction fell from 17.3% to 16.8%. The reduction in shunt fraction was significantly greater with nasal continuous positive airways pressure than in the control group (p = 0.016). There was a significant reduction (p = 0.025) in respiratory rate from 18.3 to 16.7 breath.min^{-1} during continuous positive airway pressure. Other measured cardiorespiratory variables did not differ significantly between the groups. Visual analogue scores showed no significant difference in chest pain or mask comfort between the groups. The ease of breathing score was, however, significantly better in the continuous positive airways pressure group, 7.5 (SD 1.8) cm and control 5.6 (SD 2.6) cm.

Key words

Coronary artery surgery, lung, postoperative care, equipment.
Nasal CPAP.

Coronary artery bypass surgery (CABS) commonly results in the development of pulmonary atelectasis in the postoperative period [1]. This is more pronounced when the pleura has been opened during dissection of the left internal mammary artery [2].

The use of positive end expiratory pressure (PEEP) during mechanical ventilation results in a reduction in the alveolar–arterial (A–a) oxygen gradient. Unfortunately, the beneficial effects of PEEP do not persist following extubation [3]. The aim of this study was to measure the effect of nasally applied continuous positive airway pressure (N-CPAP) on shunt fraction and oxygen delivery in a group of spontaneously breathing, extubated patients after CABS in whom, in addition to the use of saphenous vein conduits, the left internal mammary artery has also been used, resulting in opening of the left pleura. The patient acceptability of N-CPAP was also assessed.

Method

Twenty-eight male patients who had undergone elective CABS without significant complications were studied. All patients consented to take part in the study, which was approved by the hospital ethics committee. Patients were studied if they had stable angina that was not present at rest. They were not studied if they had a history of valvular heart disease, recent nasal obstruction, or significant obstructive or restrictive pulmonary disease. None of the patients studied had significant abnormalities of the lung field as measured by clinical examination or chest X ray and patients were only included if the physicians responsible for their care felt that the benefits of pulmonary artery catheterisation outweighed any potential disadvantages. The patient's height, weight and age were recorded before operation. Patients were also divided by history into current, ex (more than 6 months) or nonsmokers and their left ventricular function was classed as good, moderate or poor according to the left ventricular end-diastolic pressure (LVEDP), the ejection fraction and the appearance of the left ventricle during angiography.

Anaesthesia was induced with fentanyl and midazolam and repeated doses of these drugs were given during and after the procedure. Muscle relaxation was provided with pancuronium or vecuronium and enflurane was used in the maintenance of anaesthesia. Myocardial protection was achieved with moderate hypothermia, topical cooling and cold aortic root crystalloid cardioplegia solution. Saphenous and internal mammary artery conduits were used as previously described.

Patients received controlled ventilation postoperatively with PEEP if required, until their clinical condition allowed them to breathe spontaneously. Cardiac index, mean

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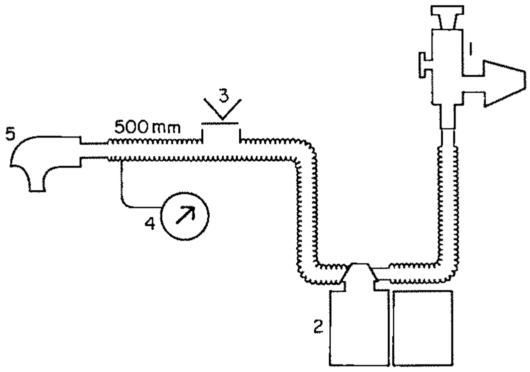

Fig. 1. Nasal CPAP circuit: 1, Downs adjustable flow generator; 2, Concha therm humidifier; 3, CPAP valve; 4, Pressure monitor line; 5, Adams pillows.

arterial pressure (MAP) and systemic vascular resistance were maintained within acceptable levels by the use of infusions of dopamine, dobutamine, nitroglycerin or noradrenaline as clinically indicated.

On the morning after surgery patients were randomly allocated to receive conventional oxygen therapy (14 patients) or 5 cmH_2O N-CPAP (14 patients). The number of coronary grafts fashioned, the duration of the operative procedure, the cross-clamp time and the bypass time were noted, as was the duration of postoperative mechanical ventilation and intubation and the time from extubation to the start of the study.

All patients breathed air-enriched oxygen through a conventional oxygen mask; the oxygen was mixed with room air using an entrainment device (entrainment nebuliser; Respiratory Care Inc. USA) and humidified with a cold water humidifier (Kendall Aquapak 03700). Patients were seated in bed at an angle of between 45 and 90°.

Indwelling pulmonary and radial or brachial artery catheters were used to record baseline values for MAP, central venous and pulmonary artery occlusion pressures (CVP, PAOP). Cardiac index was calculated from the mean of three thermodilution measurements. Pulmonary and radial artery blood samples were analysed for oxygen and carbon dioxide tensions and pH using a Ciba Corning 288 blood gas analyser. Haemoglobin concentration and the percentage of oxyhaemoglobin were measured using an Instrumentation Laboratory 482 Co-oximeter. A 10 ml gas sample was taken from in front of the patient's nose during peak inspiration and the inspired oxygen concentration was measured using the blood gas analyser. After baseline measurements had been made, patients in the N-CPAP group had CPAP applied for 60 min, using a system which we have previously described (Fig. 1). Patient connections were made using Adams pillows (Puritan Bennett Corp.) held in position with the standard headgear assembly provided. The fresh gas flow through the system was adjusted to provide a continuous leak through the CPAP valve and the pressure within the system was monitored continuously. A fuel cell oxygen analyser was used to measure the oxygen concentration within the system so that it could be maintained as near as possible to that breathed by the patient prior to CPAP. Patients were encouraged to breathe through their noses during their pre-operative visit and when the N-CPAP mask was first applied. Patients in the control group continued to breathe added oxygen from a facemask in a routine fashion.

Sixty minutes after starting N-CPAP, the baseline measurements were repeated in both the control and study groups. The inspired oxygen in the N-CPAP group was sampled from the CPAP system just proximal to the patient connection. Patients in the two groups were also asked to complete visual analogue scores, the nature of which had been explained during their pre-operative visit. These scores assessed chest pain (severe pain = 0, no pain = 10), comfort of the mask (very comfortable = 0, very uncomfortable = 10) and ease of breathing (very easy = 10, very hard = 0).

Once the measurements had been repeated, N-CPAP was discontinued and patients returned to their conventional oxygen therapy. Fifteen minutes after this, baseline measurements were again repeated in the CPAP group. All measurements in both groups were made before the patients received physiotherapy.

For parametric data, comparison between the two groups was made using unpaired Student's t-tests; within-group comparison of this type of data was made using paired Student's t-tests. Categorical variables (for example, smoking history and left ventricular function) were compared between the two groups using Chi-squared tests. Visual analogue scores were subject to logistic transformation before the two groups were compared using unpaired Student's t-tests. Significance was set at the conventional 5% level for all tests.

Results

Patients in the control and CPAP groups did not differ significantly with respect to height, weight, age, smoking history or pre-operative left ventricular function (Table 1). Left ventricular function was not assessed in one patient because of a technical difficulty during catheterisation. There was also no significant difference between the two groups with respect to the operative procedure, as measured by the number of grafts performed, the cross-

Table 1. Pre-operative data in the control and study groups.

	Patient details (mean SD)			Smoking history			Ventricular function			
	Age (years)	Weight (kg)	Height (cm)	Current smoker	Ex-smoker (over 6 months)	Non-smoker	LVEDP (mmHg)	Good	Moderate	Poor
Control	55 (10)	84 (10)	177 (6)	5	7	2	12 (2)	4	7	2 (= 13)
CPAP	59 (4)	80 (10)	172 (6)	4	10	0	13 (6)	6	5	3 (= 14)

Table 2. Operative and postoperative data in the CPAP and control groups expressed as mean (SD).

		Operative time (min)			Postoperative time (h)		
Group	Number of grafts	Cardiopulmonary bypass	Cross clamp	Total operation	1	2	3
CPAP	5.0 (1.4)	96 (37)	49 (16)	230 (59)	9.0 (3.6)	11.5 (3.6)	5.4 (4.1)
Control	4.8 (1.9)	108 (28)	44 (19)	236 (64)	9.8 (4.0)	11.3 (3.5)	5.0 (4.0)

1, End of surgery to spontaneous respiration; 2, end of surgery to extubation; 3, extubation to start of study.

Table 3. Mean values (SD) for oxygenation variables and respiratory rate in control and CPAP groups during the study period.

	Control		CPAP		
Time	0	60	0	60	75
% inspired O_2	47 (9)	47 (11)	46 (8)	46 (8)	46 (7)
% shunt	17.3 (6.8)	16.8 (7.4)	16.3 (5.7)	12.6 (6.2)	15.7 (6.0)
DO_2 index ($ml.min^{-1}.m^2$)	426 (71)	412 (80)	423 (93)	430 (83)	406 (68)
VO_2 index ($ml.min^{-1}.m^2$)	145 (40)	132 (36)	159 (31)	155 (33)	150 (30)
Respiratory rate (min^{-1})	20.5 (5.1)	22.0 (7.5)	18.3 (4.5)	16.7 (3.3)	17.5 (4.1)

clamp or bypass times or the total duration of the operative procedure (Table 2). The postoperative course before the study, as measured by the period of post-operative ventilation and intubation, and the time from extubation to the start of the study did not differ between the two groups (Table 2).

Table 3 shows the calculated values for oxygenation in the two groups as well as their respiratory rates. The shunt fraction before CPAP did not differ significantly between the two groups. However, there was a significant reduction in shunt fraction in patients using CPAP, without there being any such reduction in patients in the control group. The mean absolute reduction in shunt fraction was 3.76% (SD 4.0) in the N-CPAP group and only 0.52% (SD 2.0) in the control group, a difference that was significant ($p = 0.016$). After one hour, the shunt fraction was lower in the CPAP group than in the control group. However, this difference did not reach significance at the conventional 5% level. Fifteen minutes after discontinuation of CPAP the shunt fraction was significantly worse than during CPAP and was not significantly different from that recorded before CPAP. There was no change in oxygen delivery or extraction with the application or discontinuation of CPAP. This was because patients' haemoglobin was well saturated with oxygen before CPAP so that the reduction in shunt fraction could not result in a significant improvement in oxygen content. There was a small but significant ($p = 0.025$) reduction in respiratory rate during N-CPAP while the respiratory rate actually increased in the control group; this difference between the two groups was significant ($p = 0.038$). Table 4 shows the cardiovascular variables measured in the two groups. There was no significant difference between the two groups with respect to any of these variables before and during the application of CPAP. Within the study group no variable changed significantly with either the application or discontinuation of CPAP.

Visual analogue scores in Table 5 showed no significant-difference between the two groups with respect to chest pain or mask comfort. There was, however, a significant difference ($p = 0.007$) in favour of the N-CPAP mask with respect to the ease of breathing score (7.5 (SD 1.8) cm in the N-CPAP group and 5.6 (SD 2.6) cm in the control group). One patient found the nasal mask more uncomfortable than the conventional oxygen mask. He also found it more difficult to breathe through the mask and had an increase in shunt fraction during CPAP.

Discussion

Our results show that in patients who have had CABS in which the left pleura has been opened during internal mammary artery dissection there is a significant reduction in shunt fraction during breathing via an N-CPAP system.

Table 4. Mean (SD) values for cardiovascular variables in the control and CPAP groups.

	Control		CPAP		
Time (min)	0	60	0	60	75
Cardiac index; $l.min^{-1}.sq.m^{-1}$	3.1 (0.4)	3.1 (0.6)	3.0 (0.5)	2.9 (0.4)	2.8 (0.3)
MAP; mmHG	78 (11.7)	80 (11.4)	81 (4.4)	82 (4.0)	83 (4.5)
HR; minutes	90 (15)	90 (15)	88 (14)	90 (14)	89 (14)
CVP mmHG	7.4 (4.0)	7.1 (3.3)	7.4 (3.6)	7.2 (3.8)	7.01 (3.4)
PAOP; mmHG	8.6 (2.9)	8.0 (3.5)	8.4 (3.9)	9.15 (3.9)	8.23 (3.9)

Table 5. Mean (SD) visual analogue scores in cm for control and study groups.

	CPAP	Control
Chest pain (10 = no chest pain)	5.7 (1.5)	5.3 (2.3)
Comfort (10 = very comfortable)	6.7 (1.9)	6.2 (1.7)
Ease of breathing (10 = very easy)	7.5 (1.8)	5.6 (2.6)

Although this reduction in shunt fraction was associated with no demonstrable haemodynamic effects, the improvement was modest and was not sustained after CPAP was discontinued. We have also demonstrated that after 60 min use the CPAP mask is at least as well tolerated as a conventional facemask and that there was a small but significant reduction in respiratory rate during N-CPAP.

These results are in broad agreement with previously published work that has shown a significantly lower A–a gradient in patients treated with PEEP during mechanical ventilation [4]. This improvement was not, as in our study, sustained after the therapy was withdrawn. A reduction in A–a gradient has also been demonstrated during treatment with N-CPAP in patients with pulmonary atelectasis [5] and in patients with pneumonia [6]. Pinilla *et al.* [7] have shown a reduction in A–a gradient after saphenous vein grafting was used for coronary revascularisation in patients treated with a combination of mask and N-CPAP. This improvement was again temporary and did not result in any significant improvement in pulmonary atelectasis.

In apparent contrast to these studies, suggesting that the beneficial effects of PEEP are not sustained, other authors have shown a more rapid recovery in functional residual capacity [8] and reduction in A–a gradient [9] in patients treated with CPAP on a regular basis on each postoperative day after upper abdominal surgery. The system's patient acceptability would make it suitable for this type of application, particularly as the mask can be used during physiotherapy.

One potential disadvantage of N-CPAP, which we have described, is the loss of airway pressure during mouth breathing and this may limit its usefulness in patients with severely impaired pulmonary oxygen transfer where a full facemask will, if tolerated by the patient, produce a more continuous level of CPAP. We conclude that the use of nasal CPAP is a simple, tolerable and effective method of treating hypoxaemia in adult patients after coronary artery bypass surgery and warrants further study.

Acknowledgments

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Anaesthesia, 1992, Volume 47, pages 320–323

The effect of nitrous oxide on laryngeal mask cuff pressure

In vitro and *in vivo* studies

A. B. LUMB AND M.W. WRIGLEY

Summary

We have studied the effect of nitrous oxide on the cuff pressure of a laryngeal mask both in vitro and in vivo. In laboratory tests, we showed that nitrous oxide and carbon dioxide diffuse across the cuff wall much more rapidly than nitrogen and oxygen. Differing partial pressures of these gases across the cuff wall therefore give rise to changes in volume and pressure within the cuff. We then studied 18 patients undergoing general anaesthesia with nitrous oxide, and found a consistent and linear increase in cuff pressure in all patients. After 30 min, the mean pressure had increased by 30 mmHg, and there was approximately 10% nitrous oxide in the cuff. It is difficult to relate these findings to pressure on pharyngeal structures, but methods of limiting the rise in intracuff pressure are discussed.

Key words

Anaesthetics, gaseous; nitrous oxide.
Equipment; laryngeal mask.

It is well known that even in a relatively short anaesthetic, nitrous oxide will diffuse into the cuff of a tracheal tube, resulting in an increase in the cuff pressure [1]. The laryngeal mask (LM) is now widely used to maintain a reliable airway for many types of anaesthesia. Mostly this involves short anaesthetics, but as confidence in the device increases, its use for longer procedures will become more common. The cuff of a LM is manufactured from silicone-based rubber, a substance which is known to absorb rapidly volatile anaesthetic agents and nitrous oxide [2]. During general anaesthesia, N_2O may therefore be expected to diffuse into the air-filled cuff of the LM more rapidly than air can diffuse out. It appeared probable that cuff volume and pressure would temporarily increase during N_2O anaesthesia. We have therefore investigated the effect of N_2O on the cuff of the LM, firstly by assessing the permeability of the cuff to various gases *in vitro*, and secondly by an *in vivo* study of cuff pressures during routine anaesthesia.

Methods

Throughout the study, pressure was measured as gauge pressure using an anaeroid manometer, which was calibrated against a mercury column. Laryngeal mask cuff volumes were measured at atmospheric pressure and ambient humidity with a 60 ml syringe.

Laboratory study

The pressure volume relationships of a new size 4 LM cuff were assessed by filling the cuff with water to atmospheric pressure (zero gauge pressure), and then inflating with 1 ml increments of water at room temperature while measuring the pressure. This was performed with the mask suspended in both air and 5% enflurane in oxygen.

The remaining experiments were performed with the same LM suspended in a glass container along with a thermistor temperature probe. Gases were passed into the container at a flow rate of approximately 6 $l.min^{-1}$, the gas leaving the container via the LM lumen. Having first thoroughly flushed all air from the cuff by filling and evacuating it three times with the gas under test, the cuff was evacuated to a pressure of 80 mmHg below atmospheric, and then inflated to a pressure of +80 mmHg (approximately 30 ml). The cuff pressure was then measured at 1–10 min intervals depending on the rate of change. Three experiments were performed: (1) Oxygen, nitrogen, carbon dioxide, and nitrous oxide were each in turn placed in both the cuff and the container, and the cuff pressure recorded for 1 h. Under our standard conditions of cuff inflation this provided a pressure difference of 80 mmHg of a single gas from the inside to the outside of the cuff, and so changes in pressure reflected the diffusion of that gas across the wall of the cuff. (2) The cuff was filled with N_2O, with air in the container, and cuff pressure

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measured for 30 min. This was then repeated with air in the cuff and N_2O in the container. The volume of gas in the cuff was measured both before and after the experiment. (3) Experiment 2 was repeated with CO_2 and air instead of N_2O and air. All laboratory studies were carried out at room temperature (20 ± 1°C).

Patient study

We studied 18 elective surgical patients in whom the anaesthetist responsible for the case intended to use an anaesthetic technique with a LM, and in whom the duration of anaesthesia was expected to be over 30 min. The anaesthetic technique studied consisted of an opioid and anticholinergic premedication, induction with propofol, insertion of a size 4 LM, and maintenance with 66% N_2O in oxygen and enflurane 0–4% with spontaneous respiration via a Mapleson A breathing system. Before induction, the LM cuff was deflated to 80 mmHg below atmospheric, and following insertion it was then inflated to 80 mmHg above atmospheric with room air, and the required volume of air recorded. Cuff pressure readings were then taken for 30 min at 5 min intervals. The cuff was then deflated to the same vacuum, and the gas volume recorded, before reinflation of the cuff.

In the last six subjects, the concentration of O_2, N_2, N_2O, and CO_2 was measured in the gas extracted from the cuff after 30 min of anaesthesia. Measurement was by mass spectrometry (Medishield, MS2) calibrated with air and volumetrically prepared standards. Cuff pressure at 30 min after insertion was compared with that at time 0 (80 mmHg) by a paired Student's *t*-test.

Results

Laboratory study

There were no significant changes in temperature of the LM during the experiments.

The elastance ($\Delta P/\Delta V$) of the cuff was constant between 25 and 150 mmHg (Fig. 1), and this curve was identical after exposure of the LM to 5% enflurane for 1 h.

All four gases tested diffused across the cuff down a pressure gradient of 80 mmHg, but the cuff was considerably more permeable to N_2O and CO_2 than nitrogen or oxygen (Fig. 2). This was confirmed by the second part of the study, where N_2O on the outside of the cuff diffused inwards faster than air diffused outwards, causing an increase in the cuff volume from 33 ml to 64 ml, and a pressure increase of almost 200 mmHg (Fig. 3). Conversely, N_2O in the cuff diffused outward with a reduction in volume of 34 ml, and a decrease in the cuff pressure of 130 mmHg, resulting in a substantial vacuum in the cuff (Fig. 3). A similar picture was seen with CO_2, though the pressure changes were less.

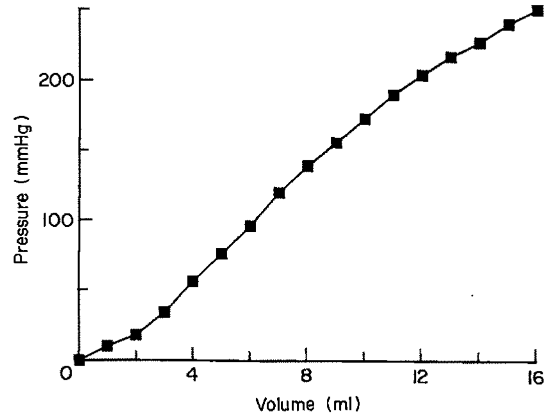

Fig. 1. Pressure–volume relationship for the cuff of a water-filled size 4 LM, commencing at atmospheric pressure (zero gauge pressure).

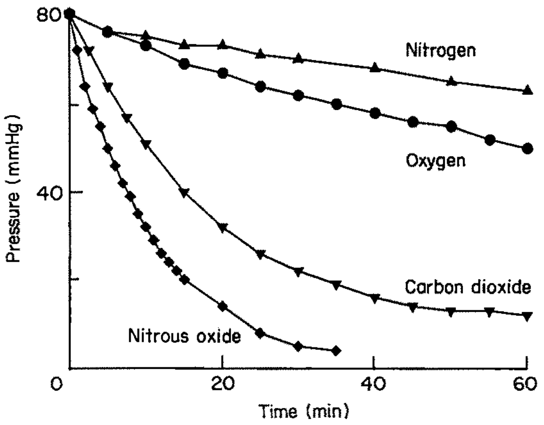

Fig. 2. Pressure changes with the same gas both inside and outside the LM cuff, reflecting ability of gases to diffuse across the LM cuff wall down a pressure gradient of 80 mmHg.

Patient study

The 18 patients had a mean age of 51 (range 19–90) years. Cuff pressure increased progressively in all subjects (Fig. 4), and the increase in pressure between time 0 and 30 min was highly significant ($p < 0.001$). The volume of gas in the LM cuff also increased in all subjects, with a mean increase of 5.1 (range 2–9) ml in 30 min. Analysis of gas concentrations in the cuff after 30 min showed mean concentrations of O_2 17.1%, N_2 69.4%, CO_2 2.2%, and N_2O 10.0% ($n = 6$).

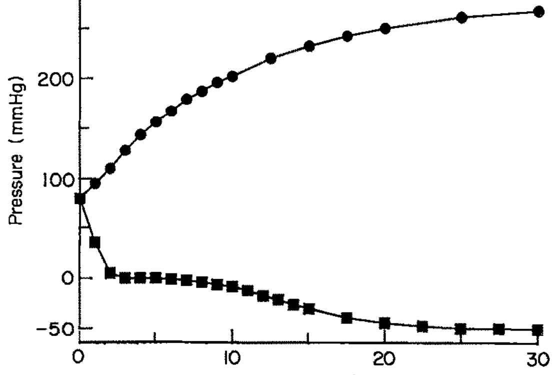

Fig. 3. Pressure changes caused by selective diffusion of N_2O compared with air across cuff wall. ●, air in cuff, N_2O atmosphere; ■, N_2O in cuff, air atmosphere.

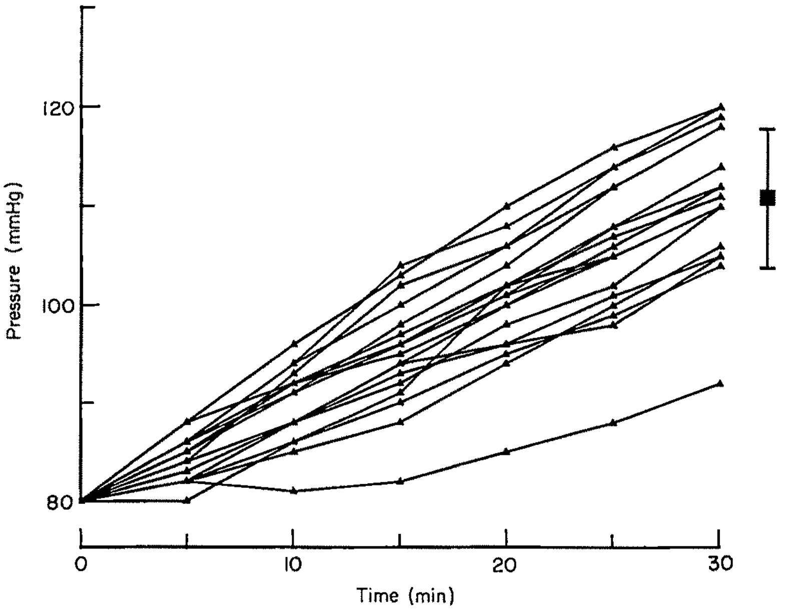

Fig. 4. Individual patient changes in LM cuff pressure during 30 min of anaesthesia with 66% N_2O. ■, mean pressure at 30 min; error bars, SD.

Discussion

Our *in vitro* study has shown that the cuff of a new laryngeal mask is much more permeable to N_2O and CO_2 than oxygen or nitrogen. Nitrous oxide, and to a lesser extent CO_2, will therefore diffuse across the wall of the cuff more rapidly than air, the amount and direction of this diffusion being dependent on their partial pressures inside and outside the cuff. In patients, the air with which the cuff is initially inflated contains neither CO_2 or N_2O, but when in the patient, the cuff is exposed to relatively high partial pressures of both CO_2 and N_2O, particularly that part of the cuff which is in contact with respiratory gases rather than the pharynx. Thus it may be predicted that during anaesthesia, N_2O and CO_2 will diffuse into the cuff more rapidly than air will diffuse out, giving rise to an increase in cuff volume and therefore pressure. In the *in vivo* part of the study we have shown an increase in cuff pressure and volume during anaesthesia, and demonstrated that N_2O and CO_2 have diffused into the cuff.

Air used to inflate the cuff of a LM will also be warmed, and therefore expand, when in the pharynx. Though this will undoubtedly contribute to our findings, it cannot fully explain the observed increase in pressure, as from Charles' Law, increasing the temperature of 30 ml of gas from 20°C to 37°C will only increase its volume by 1.74 ml.

The pressure increase resulting from an increase in cuff volume depends on the elastance of the system (Fig. 3). It can be seen that the curve is essentially linear in the clinically applicable area of cuff pressures between 25 and 150 mmHg. One factor which may influence the physical properties of the rubber is the volatile agent dissolving in the rubber of the cuff, thereby altering its elastance. This was not seen after one hour of exposure to 5% enflurane, so is unlikely to be of relevance clinically.

The effect of this increase in LM cuff pressure on the pharynx *in vivo* is difficult to assess. Tracheal mucosal damage from overinflated tracheal tube cuffs was reported following quite short periods of anaesthesia [3]. In this case, the cuff is confined within the trachea which is a semirigid container whose shape is relatively uniform in comparison with the pharynx. However, even under these circumstances, measurement of the pressure exerted on the tracheal mucosa is complex, and still not clearly understood [4]. The pharynx is both more complex in shape, and far more distensible than the trachea. It is also normally subjected to very large pressure changes and distortion under many physiological circumstances such as swallowing and coughing. We therefore cannot predict what effect our observed intra-cuff pressures will have on the pharynx and surrounding structures. It is however possible that damage could occur by compression of parts of the pharynx against surrounding structures such as the hyoid bone or cervical vertebrae. There is no evidence yet of pharyngeal damage occurring with the LM, and sore throats occur in only 8% of patients [5], which compares very favourably with an incidence of 18% with anaesthesia via a facemask [6].

It is difficult to avoid the increase in cuff pressure during administration of nitrous oxide, but there are four possible methods, all of which have been advocated for use with tracheal tube cuffs. Firstly, filling the cuff with the gas mixture to be used for anaesthesia will not be effective, as from Figures 1 and 2 it can be seen that 66% N_2O would diffuse out of the cuff in only a few minutes regardless of the gas mixture outside the cuff. Secondly, filling the cuff with water would prevent pressure changes but would risk tracheal aspiration of several ml of water, and heat sterilisation of the LM would boil any residual water and rupture the cuff. Thirdly, pressure relief valves could be fitted, many of which have been used for tracheal tubes [7]. Finally, the cuff pressure may be monitored, and the cuff deflated when needed. The latter method is simple, effective, and the most readily available, and should be considered in all patients undergoing anaesthesia with N_2O via a LM for over 30 min.

Acknowledgments

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Topical nonsteroidal anti-inflammatory gel for the prevention of peripheral vein thrombophlebitis

A double-blind, randomised, placebo-controlled trial in normal subjects

J. J. PAYNE-JAMES, M. J. BRAY, S. KAPADIA, S. K. RANA, D. MCSWIGGAN AND D. B. A. SILK

Summary

A double-blind, randomised, placebo-controlled study was undertaken to determine whether topical application of a nonsteroidal anti-inflammatory gel to skin overlying peripheral vein cannula sites has a role in reducing the incidence or delaying the onset of peripheral vein thrombophlebitis. Fifty normal subjects had intravenous cannulae placed in right and left arms. Subjects were randomised to receive twice daily application of either active nonsteroidal anti-inflammatory gel or placebo gel to each cannula site. Cannula sites were observed and signs and symptoms of inflammation recorded up to 108 h. If any site had signs extending beyond 2 cm then the cannula was removed. Cannula sites that had 'active' gel applied had half the incidence of marked signs at 108 h (44% vs 22%, $p < 0.05$). These results suggest that local application of topical nonsteroidal anti-inflammatory gel to cannula sites may have a significant role to play in the prevention of peripheral vein thrombophlebitis.

Key words

Nonsteroidal anti-inflammatory drugs; felbinac gel.
Thrombophlebitis, peripheral vein; prophylaxis.

Peripheral vein thrombophlebitis (PVT) is a major source of morbidity in hospital practice. At least 6 000 000 peripheral vein cannulae are sited in the United Kingdom each year, of which at least 10% will develop thrombophlebitis [1]. PVT is clinically recognised by signs of local pain, erythema, swelling or hardness associated with the indwelling cannula. The clinical definition of 'thrombophlebitis' is unclear and different researchers have used different scoring or grading systems. In clinical practice, excessive pain, infusion failure (because of vein occlusion) or extravasation are often the determinants of whether 'thrombophlebitis' is present. Various groups have explored ways of reducing the incidence of PVT by counteracting the causative influences using techniques such as the addition of heparin or corticosteroids to the infusion solution, buffering the solution and in-line filtration [2]. A different approach, targeting the vein rather than each specific cause of PVT, showed that prophylactic local transdermal application of glyceryl trinitrate significantly reduced the incidence of thrombophlebitis and prolonged cannula usage [3]. The availability of topically applied nonsteroidal anti-inflammatory drugs (NSAID) has allowed an investigation to determine whether the incidence of PVT may be reduced, or its onset delayed, by topical application of such a drug.

Methods

The study was approved by the District Ethics Committee and informed consent was obtained from healthy volunteers for inclusion in the study. Pregnant females and subjects with hypersensitivity or intolerance to NSAIDs, bleeding diatheses, and current anticoagulant or NSAID ingestion were not studied. Each subject was to have two peripheral cannulae (PTFE-Teflon 18G, Vasculon 2, Viggo-Spectramed AB), inserted into symmetrical forearm veins. Subjects were randomly assigned for each forearm to receive either felbinac (biphenyl acetic acid) 3% gel (Traxam, Lederle Laboratories) or an inactive placebo gel. All cannulae were inserted by the same investigator, who was experienced in cannula insertion. In each case cannulae were sited in 3–4 mm diameter veins in the midforearm,

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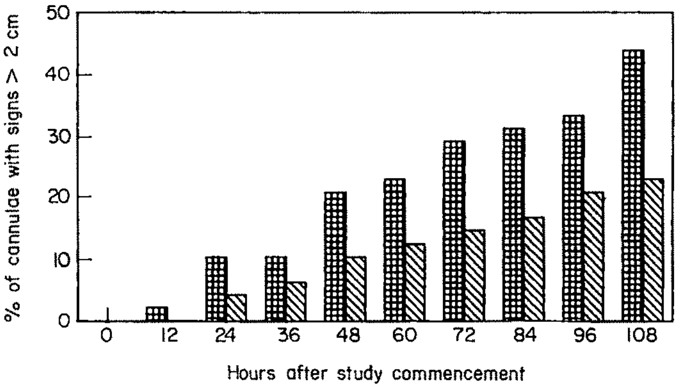

Fig. 1. Cumulative percentages of cannulae developing signs > 2 cm ($p < 0.05$ at 108 h). ▦, placebo; ▧, felbinac gel.

away from the wrist or elbow joint; veins were distended with an above-elbow tourniquet. The insertion site was not shaved, but each site was sprayed with chlorhexidine-gluconate and left for 2 min to air dry. After the cannula had been sited in the vein, the introducer needle was removed, and the cannula capped with a sterile Luer-lock stopper with an injection port (891, Vygon, UK). Each cannula was then flushed once through the injection membrane with 2 ml of heparinised saline (Hepsal, CP Pharmaceuticals Ltd). Each cannula hub was covered and fixed in place with a transparent dressing (Tegaderm, 3M Medical-Surgical Division). A 3 cm ribbon of the assigned gel (approximately 1 g) was applied to the cannula site and rubbed in until the skin was dry. This was repeated every 12 h up to 108 h after cannula insertion. Gel application was undertaken in a double-blind manner, with investigators and subjects being unaware of the randomisation.

Cannula assessment

All cannulae were examined twice daily up to 108 h. Each cannula was assessed at three sites: at the insertion site (where the cannula penetrated the skin), at the site of the tip of the cannula within the vein (determined by the length of the cannula from the insertion site), and over the midpoint of the cannula (midway between the tip and insertion). Assessment of pain and three signs (erythema, oedema, and palpable hardness) were made at each site. The site was recorded as positive for pain if the subject commented on discomfort following the application of light pressure with the investigator's index finger. The degree of intensity of each sign was graded for each site according to the area involved as less than 1 cm, between 1 and 2 cm or greater than 2 cm. The cannulae were removed at 108 h, unless there were any signs greater than 2 cm (defined as 'thrombophlebitis' in this study) or if the subject requested removal because of pain, even in the absence of signs. After removal, cannula tips underwent microbiological assessment using the semiquantitative solid medium method [4].

Statistical analysis

Comparison of frequencies of complications after each 12 h period was undertaken with the McNemar Chi-squared test using continuity correction.

Results

A total of 50 subjects were studied (mean age 34.5 years, SEM 1.0). Figure 1 shows the cumulative percentage of cannulae removed after each 12 h period throughout the study when any sign was greater than 2 cm in length, irrespective of site. The NSAID gel treated cannulae had consistently less 'thrombophlebitis' at all time points in the study, significantly so at 108 h ($p < 0.05$).

Table 1 lists the complication frequency for both cannulae irrespective of time of appearance, by comparing: the overall number of signs present irrespective of site, the number of sites involved irrespective of signs and each sign at each site. Table 1 shows that felbinac treated cannulae

Table 1. Complication frequency, independent of time (comparison of paired cannulae).

	Number of felbinac treated cannulae performing better than placebo	Number of placebo-treated cannulae performing better than felbinac	p
Sign			
Erythema (E)	4	3	1.000
Oedema (O)	5	3	0.727
Hardness (H)	12	2	0.013*
Pain (P)	11	5	0.210
Site			
Insertion (I)	4	5	1.000
Midpoint (M)	11	3	0.057
Tip (T)	9	2	0.065
Sign and site			
Erythema; insertion (EI)	1	4	0.063
Erythema; midpoint (EM)	5	2	0.453
Erythema; tip (ET)	6	2	0.289
Oedema; insertion (OI)	3	2	1.000
Oedema; midpoint (OM)	4	3	1.000
Oedema; tip (OT)	3	1	0.625
Hardness; insertion (HI)	4	0	0.125
Hardness; midpoint (HM)	11	0	0.001*
Hardness; tip (HT)	8	2	0.289
Pain; insertion (PI)	14	4	0.031*
Pain; midpoint (PM)	11	9	0.824
Pain; tip (PT)	10	6	0.454

*Significant differences.

tended to perform better for each parameter measured (apart from EI, erythema at insertion site; and I, the number of insertion sites with signs). Significantly better performances (at the 5% significance level) for the felbinac treated cannulae were observed for hardness over the catheter midpoint, hardness at all sites and pain at the insertion site. Two felbinac (4%) and one placebo (2%) treated cannula cultures yielded significant growth of organisms (> 15 colony forming units) — all were staphylococci. There was no significant difference between these two figures. Colonized felbinac cannulae showed no clinical evidence of thrombophlebitis at 108 h, whilst the colonized placebo cannula required removal at 24 h. No adverse reactions were recorded in either felbinac or placebo gel treated cannula sites.

Discussion

Peripheral vein thrombophlebitis (PVT) develops in 10–57% of patients with intravenous peripheral lines [1,5,6]. PVT may result in pain, extravasation, intravenous line failure, loss of venous access, progressive loss of peripheral veins, and occasionally bacteraemias and septicaemias [1]. Thus PVT may necessitate replacement of intravenous cannulae, and require local or systemic treatment for pain relief or infection, all of which will increase the costs of patient care. Increasing use of peripheral administration of total parenteral nutrition, where thrombophlebitis is the limiting factor [7], has recently increased awareness of other methods of prophylaxis of PVT. The use of a prophylactic measure that nonspecifically targets the inflammatory changes associated with PVT is appealing, and has previously been investigated [8]. Nonsteroidal anti-inflammatory drugs, have been assessed in the treatment of established thrombophlebitis [9], but until now not studied in a prophylactic role. The inflammatory changes associated with the intravenous cannulae in this study were significantly reduced by the active gel. Almost half (44%) the cannulae treated with placebo developed signs > 2 cm by 108 h (this figure being almost identical to the results in a previous comparison of cannula materials [2]), compared with only 22% of the felbinac-treated cannulae, a reduction in incidence of 50%. If this effect could be translated to the clinical situation, at least 300 000 (half of the 600 000 potential cases each year, assuming a minimum 10% PVT rate) potential episodes of PVT may be avoided each year. It will be important, however, to define those patients at higher risk of developing PVT so that such prophylaxis can be selectively targeted to ensure cost benefit. The results of this study in normal subjects have demonstrated that the topical local application of the felbinac gel appears to significantly reduce the incidence (and thus delay onset) of the inflammatory changes associated with PVT. This effect should now be investigated in the clinical setting in prospective, randomised, placebo-controlled clinical trials.

Acknowledgments

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Preparation of the critically ill for interhospital transfer

C. J. RUNCIE, W. R. REEVE AND P. G. M. WALLACE

Summary

Changes in monitoring and therapy during the preparation of 100 critically ill patients for interhospital transfer by a specialist team were documented prospectively with the aim of providing guidelines for nonspecialists. Severity of illness scores were recorded before and after preparation. Median duration of preparation for ambulance journeys was 50 min and for aeroplane journeys was 82 min. During preparation, a portable electrocardiogram and pulse oximeter were attached to 21 and 76 patients respectively and intra-arterial pressure monitoring was continued or instituted in 88 patients. Supplemental oxygen and intravenous fluids were the therapies most commonly increased or instituted by the transport team; mechanical ventilation, positive end-expiratory pressure and inotropic drugs were increased or instituted less frequently. Median therapeutic intervention scores before and after preparation were 21 and 23 respectively, highlighting the need to increase rather than withdraw support for transfer.

Key words

Critical care; transport.

Secondary transport involves the movement of patients already in hospital to another hospital with more appropriate facilities for their further management. A recent survey [1] estimated that 10 000 patients with life-threatening illness are transported between hospitals annually in the UK; 92% of transported patients were accompanied by an anaesthetist. Recommendations to concentrate resources and expertise in regional intensive care units (ICUs) supported by a network of high dependency units [2] will almost certainly increase the numbers of critically ill patients who require secondary transport.

Deterioration during transport with adverse outcome was described some years ago [3], but recent reports [4–6] suggest there has been no improvement in standards of care for such patients. Bion *et al.* [4] found that seven of 50 patients transported within a district general hospital group suffered life-threatening complications during the journey; 34 of these patients were accompanied by an anaesthetist. Gentlemen and Jennett [5] reported hypoxia in 15%, hypotension in 7% and inadequately treated extracranial injuries in 10% of head-injured patients transferred to a regional neurosurgical unit. Transfer of critically ill patients without deterioration is possible if thorough assessment and stabilisation are achieved before, and close monitoring applied during, transfer [7]. Specialist teams have described the equipment and monitoring requirements [8, 9] but no clear guidelines concerning preparation for transfer are available to nonspecialists.

The aims of this study were to document the therapies employed by a specialist team during the preparation of critically ill patients for secondary transfer and to examine resultant changes in APACHE II [10] and Therapeutic Intervention Scoring System (TISS) [11] scores, with the ultimate aim of providing guidelines for safer transfer of the critically ill.

Patients and methods

The secondary transport team attached to this hospital comprises two anaesthetists and one surgeon, and is responsible for transporting critically ill adults between hospitals in the west of Scotland. Patients are transported either to regional dialysis or neurosurgical units (some of these may come from ICUs) or for intensive care if the base hospital has no such facilities. All these journeys are by ambulance. In addition, a number of patients (eight in this study) are transported by air, either from the Western Isles to Glasgow or from Glasgow to transplant centres in the south.

One hundred consecutive patients transferred between hospitals over an 8-month period were studied. All data were collected prospectively. Demographic details, diag-

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Table 1. Demographic details and diagnostic categories.

Age; years	Median	51	
	Range	15–89	
M : F ratio	58 : 42		
Diagnostic categories	Neurological		19
	Cardiovascular		
	septic shock (excluding gastrointestinal causes)		5
	haemorrhagic shock		6
	other		3
	Gastrointestinal obstruction/perforation		9
	Respiratory		
	failure/postoperative IPPV		11
	infection		5
	Trauma		13
	Poisoning		2
	2-system failure (including renal failure)		17
	Miscellaneous		10

nosis, source of referral, destination and the durations of preparation and transfer were noted for each patient. APACHE II and TISS scores were recorded on arrival of the team at the referring hospital and after preparation just prior to departure. Where possible, separate blood samples were taken at each point to allow calculation of the APACHE scores; when preparation was rapid, results from one blood sample were used for variables with a long time-constant. Resuscitation of patients for transfer was to end-points dictated by transport-team protocols. Details of resuscitation, including changes in monitoring, were recorded on a standard proforma.

Details of our physiological monitoring have been published previously [8, 9] and this was supplemented by the referring unit's equipment. Where intermittent positive pressure ventilation (IPPV) was necessary, a gas-powered Drager Oxylog portable ventilator (Draegerwerk AG, Luebeck, Germany) was employed. Mortality in transit or in the destination unit was recorded.

Analysis of group means was by the Kruskal–Wallis analysis of variance for data which are not normally distributed [12]; $p < 0.05$ was taken to indicate significant differences. For APACHE II variables which change rapidly the frequency with which preparation of the patient returned abnormal values to zero scores was calculated.

Results

Demographic details and diagnoses for the patients are listed in Table 1. Sources of referral (i.e. sites of patient preparation) were operating theatre recovery areas (17 patients), general wards (24 patients), ICUs (18 patients), the regional neurosurgical unit (17 patients), accident and emergency (A + E) departments (11 patients), coronary care or high dependency units (11 patients) and nearby airports (two patients). Eighty-two transfers were to two regional ICUs or the regional neurosurgical unit; four were to transplant centres in England. The median durations of preparation and transfer for ambulance journeys were 50 and 25 min respectively, while for aeroplane journeys they were 82 and 132 min.

TISS scores were calculated satisfactorily for 95 patients. Of 44 patients with a TISS score < 20 on arrival, there was

Table 2. TISS and APACHE II scores on arrival of the transport team and after preparation for transport, and duration of preparation by referral source. Data are presented as mean, median. The p-value is for Kruskal–Wallis analysis of the population means of the referral source groups.

		TISS		APACHE II		
	No.	On arrival	After preparation	On arrival	After preparation	Duration (min)
Overall	95	21, 21	23.5, 23	14.2 14	14.2, 14	62.3, 55
Theatre	17	28, 28	29.7, 31	9.8, 10	10, 10	52, 45
HD/CCU	11	22.3, 24	25.4, 25	18.6, 19	19.6, 20	94.5, 70
A + E Dept.	10	11.2, 10	13.9, 12	11.8, 14.5	11.4, 13.5	34.5, 27
ICU	16	28.1, 28	28.1, 28	17.9, 20	16.7, 19.5	69.7, 62
RNC	15	23, 22	23.9, 23	13.2, 12	13.5, 12	48.7, 50
Ward	24	13.3, 11	19.2, 19	14.9, 14	14.8, 15	73.3, 55
Airport	2	23.5	24	10	11.5	45
p-value		0	0.0002	0.0049	0.0088	0.0301

A + E = accident and emergency, HD/CCU = high-dependency or coronary care unit, RNC = regional neurosurgical centre, ICU = intensive care unit.

Table 3. TISS and APACHE II scores on arrival of the transport team and after preparation for transport, classified by survival in the destination unit. Data are presented as mean, median. * = $p < 0.05$.

	Survivors	Nonsurvivors	
TISS			
On arrival	19.7, 20	25.2, 27.5	*
After preparation	21.9, 22	29.2, 28.5	*
APACHE II			
On arrival	12.8, 12	20, 19.5	*
After preparation	13, 12	19.4, 19	*

Table 4. Monitoring during preparation.

	Not used	In use on arrival	Instituted by team
ECG	3	76	21
Oximeter	0	24	76
Direct BP	12	35	53
CVP	41	52	5

CVP = Central venous pressure.

an increase of 10 points or more during preparation in 10 patients (maximum 21 points in two patients). Of 51 patients with an initial score > 19, an increase of 10 points or more occurred in only one. Where IPPV was instituted during preparation, TISS score increased from a median of 15 to 27 ($p = 0.0005$); for the remaining patients scores were 22 before and after preparation. TISS scores from each referral source are detailed in Table 2.

APACHE II scores before and after preparation for the 95 patients in whom TISS scores were calculated are also noted in Table 2, as are APACHE scores from each referral source. There was no significant change in APACHE score when patients were classified into three groups according to their score on arrival (< 10, 10–19, > 19). Re-analysis of the scoring data based on survival in the destination unit indicated that both TISS and APACHE scores for nonsurvivors were significantly greater than for survivors before and after preparation (Table 3).

Details of monitoring and resuscitation procedures are shown in Tables 4 and 5. Inspired oxygen concentration was increased during preparation from a median of 50% to 60%; $Sp\text{O}_2$ was < 90% before preparation in 13 patients, but exceeded 92% in all patients after preparation, with a mean increase of 12.4% (range 6–22%). The median volume of fluid administered to 99 patients was 100 ml (mean 309, SD 392). One patient required a laparotomy for intra-abdominal bleeding during the preparation period and received transfusion of 20 litres of blood, colloid and crystalloid.

Twenty-one patients received no drugs during preparation and details of drugs given were incomplete in a further 20 patients. Of the remainder, 23 patients received a benzodiazepine, 35 received an opioid and 41 received a nondepolarising neuromuscular blocker (most received more than one drug). Drugs given less commonly included propofol (six patients), bronchodilators and vasodilators (four patients each), thiopentone, etomidate, calcium and mannitol (three patients each), suxamethonium, steroids, insulin, heparin, digoxin, labetalol and phenytoin.

Improvements in APACHE II variables which change rapidly are detailed in Table 6. Mortality in transit was zero and in the destination units was 24%.

Discussion

A rigorous assessment of the validity of different treatment goals during preparation for interhospital transfer would pose ethical problems and the best that can be achieved is an observational study such as this. Another limiting factor in this study is the heterogeneity of the patient population as shown by the data on diagnoses and sources of referral. While making analysis difficult, it does highlight the need to employ staff with experience in all aspects of intensive care to transport critically ill patients.

A more important problem is that the therapies identified by this study may reflect the protocols of this transport team rather than the requirements of the patients studied. The invariable aim of preparation is to stabilise the patient in a condition which allows transport at normal road speeds, if necessary over long distances, with invasive monitoring and controlled ventilation maintained and resuscitation equipment to hand. The principles involved have been well described recently [13] and are drawn from the experience accumulated since the team's inception in 1975 as there is little scientific guidance in this area. Hypovolaemic dogs tolerate movement poorly [14] and a recent study demonstrated an increased alveolar–arterial oxygen difference in patients during transport [15]. These findings support the use of increased fluid therapy and high inspired oxygen concentrations during preparation for transport. Validity of the protocols is perhaps indicated by the 0% mortality in transit in a series of published studies from this unit [7, 15–17]; the number of patients transferred without a death in transit now approaches 3000.

Table 5. Changes in therapy during preparation.

			In use on arrival		
	Not used	Instituted by team	Increased	Not changed	Reduced/ stopped
Oxygen	8	3	45	37	7
IPPV	26	14	7	51	2
PEEP	70	10	2	19	0
Inotropic drugs	64	5	9	16	6
Fluids	12	7	26	55	0

IPPV = Intermittent positive pressure ventilation, PEEP = positive end-expiratory pressure.

Table 6. Effect of preparation on APACHE II variables.

	No of patients with abnormal values before preparation	No. of abnormal values improved by preparation (%)
Temperature; °C < 35.9	6	1 (17%)
> 38.4	5	1 (20%)
Mean BP; mmHg < 70	17	8 (47%)
> 109	18	5 (28%)
Heart rate; beat.min^{-1} < 70	5	0
> 109	35	6 (17%)
Respiration rate; breath.min^{-1} < 12	16	5 (31%)
> 24	21	13 (62%)
$P\text{a}O_2$; mmHg < 70	12	11 (92%)
pH < 7.33	26	7 (27%)
> 7.49	12	3 (25%)

Our results suggest that minimum monitoring during preparation of the critically ill for secondary transport comprises electrocardiography and pulse oximetry. Surprisingly, many patients were not monitored by either of these techniques (24 and 76 patients respectively) before the team arrived, although transfer by mobile ICU had been requested. Fifty-three patients required insertion of an arterial cannula during preparation, allowing direct measurement of arterial pressure in transit in 88 of the 100 patients studied. Recent studies [8, 9] from this group have documented substantial inaccuracies in indirect blood pressure measurement in transit and this technique is not recommended. More patients had a central venous catheter in place on team arrival (52) and only five required insertion of a catheter during preparation. Central venous pressure was not measured in transit as the portable monitor employed (the Simonsen and Weel Diascope 2, chosen for its robustness and battery life) has only one direct pressure channel, but measurements were used to guide fluid therapy during preparation. Patients in whom central venous pressure was not measured during preparation were usually being transferred rapidly to the neurosurgical unit for treatment, or away from that unit to general ICUs because of weaning problems. This variability in monitoring requirements makes rigid guidelines inappropriate and indicates that critically ill patients need to be transported by experienced staff equipped with portable ECG, $S\text{p}O_2$ and direct pressure monitors.

Common therapies in use on arrival were supplemental oxygen, intravenous fluids and IPPV and these were also the three therapies most commonly increased or instituted during preparation. Increased fluid therapy represented either more rapid administration, or a change from crystalloid fluids to colloid fluids or blood products. In 12 and 14 patients respectively, PEEP and inotropic drugs were increased or instituted to improve oxygenation or tissue perfusion during preparation if these had not responded to simpler measures. Again appropriate equipment (a portable ventilator with a range of PEEP valves, and portable infusion pumps) is essential. Manual ventilation with a resuscitation bag or Mapleson C system and gravity-feed infusion systems are unreliable in moving ambulances. Most drugs given during preparation were for sedation, commonly morphine (0.2–0.5 mg.kg^{-1}) and vecuronium (0.2–0.3 mg.kg^{-1}). The wide range of other drugs given highlights the need for doctors who transport critically ill patients to be familiar with the full range of intensive care drugs.

APACHE variables which change rapidly (temperature, mean arterial pressure, heart rate, respiratory rate, $P\text{a}O_2$ and pH) were studied to clarify physiological changes during preparation. Tachypnoea, hypotension and hypoxaemia were the abnormalities improved most commonly by preparation with increased fluid therapy and the institution of mechanical ventilation. Unfortunately, rigid guidelines on levels of physiological variables to be attained during preparation are inappropriate because qualitative clinical changes are important (particularly changes in peripheral perfusion) and because such goals may be unattainable in a few patients during preparation. Only experienced staff can assess this clinical and monitored information rationally to determine the most appropriate timing of transport in patients who are difficult to resuscitate.

The data on APACHE and TISS scores in Table 2 show that there are statistically significant differences among the population means of the groups being compared but do not pinpoint which populations differ from the others. This is a limitation of the Kruskal–Wallis analysis of variance. Despite this, scores from the respective referral sources are consistent with their expected roles and patient populations in the West of Scotland. Patients transferred from operating theatre recovery areas have high TISS scores (most are mechanically ventilated and invasively monitored) but low APACHE scores, while patients referred from ICUs show a similar degree of intervention but higher APACHE scores. In both, scores changed little with preparation. In contrast, patients referred from general wards and accident and emergency departments had low TISS and intermediate APACHE scores before preparation. TISS scores were static in the A+E group as these were frequently patients transferred to the neurosurgical unit with minimum monitoring and few additional therapies, while

TISS score increased from 11 to 19 in ward patients as these patients often required institution of mechanical ventilation and invasive monitoring in the ward during preparation.

The shorter duration of preparation in A+E departments is also consistent with their expected patient population. The duration of preparation in other referral sources highlights the need for meticulous preparation before transfer. In 25% of transfers from wards, preparation time exceeded 2 h. For transfers by ambulance, the ratio of preparation time to journey time was 2:1. Confirmation of the need for meticulous preparation comes from the changes in TISS scores; it is clear that monitoring and support were increased for transfer rather than withdrawn because of lack of equipment or expertise.

We suggest, therefore, that this study highlights the need for thorough (and if necessary protracted) preparation of the critically ill before interhospital transport. This involves attachment of a portable electrocardiogram and pulse oximeter in almost all patients and insertion of an arterial cannula in most (if not present already). Most patients require increases in fluid therapy and inspired oxygen concentration; a smaller number require therapy with PEEP or inotropic drugs, or even institution of mechanical ventilation. Patients prepared in this way, using appropriate equipment, can be transported safely at normal road speeds over long distances. The variety of diagnoses, referral sources and drugs administered and the difficulty of applying rigid guidelines to monitoring and treatment indicate that interhospital transport is the province of experienced staff.

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A clinical evaluation of the 'Rapitrach'

A bedside percutaneous tracheostomy technique

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Summary

A number of percutaneous tracheostomy devices are now available commercially. We report a preliminary clinical study of the use of the 'Rapitrach' kit (Fresenius, Runcorn, Cheshire, UK). Twenty critically ill adult patients underwent tracheostomy using the kit. Nineteen of the procedures were carried out at the bedside in the intensive therapy unit. Correct tube placement was achieved in all cases.

Key words

Equipment; tubes, tracheostomy.

The introduction of methods for percutaneous tracheostomy follows the general trend in surgery to minimise tissue trauma. Such techniques allow the skin incision to be small with minimal disruption of deeper tissues and no tracheal resection. This should limit the risk of bleeding, infective complications and scar formation. The use of these techniques at the bedside in the intensive therapy unit (ITU) avoids the risks associated with moving the critically ill patient. Percutaneous trachoestomy is performed often by clinicians who are not trained primarily in surgery. We have evaluated the use of the 'Rapitrach' [1] technique for the placement of a standard 8 mm plastic cuffed tracheostomy tube. The use of this device followed our experience with other dilational techniques [2].

Method

All patients had an oro/nasotracheal tube *in situ* and were receiving assisted ventilation. Anaesthesia was provided by an anaesthetist who took no part in the surgical procedure. The patient was positioned as for conventional tracheostomy. A combination of intravenous alfentanil and propofol was used, avoiding the need for an anaesthetic machine at the bedside. Muscle relaxation was not required routinely. When the patient was anaesthetised, the tracheal tube was withdrawn until the cuff was seen to lie in the larynx; this avoided later transection of the tracheal tube or cuff with the needle and guidewire.

The neck was prepared and draped as for conventional tracheostomy. It was our practice to infiltrate subcutaneously with lignocaine 1% with 1:100000 adrenaline. A 1–2 cm horizontal incision was made midway between cricoid cartilage and sternal notch. The incision was made at a lower point in patients with a hyperinflated chest or short neck. The incision was made just through the skin, and subcutaneous layers were then dissected bluntly with a pair of forceps. Superficial midline veins were identified and avoided. Blunt dissection was continued to push the strap muscles aside until a finger could be inserted and the tracheal rings palpated. A 12 gauge needle was then inserted into the trachea between 1st and 2nd, or 2nd and 3rd rings, and its correct placement confirmed by free aspiration of air into a fluid-filled syringe. The tracheal tube was moved back and forth to confirm that the needle had not transected it. A short flexible guidewire was then inserted into the trachea, and the needle removed.

A pair of specially designed forceps (the 'Rapitrach' device; Fig. 1) were introduced into the trachea over the guidewire. The jaws of this device are grooved to allow its passage over the guidewire and it has a bevelled tip (Fig. 2) to aid its passage into the trachea. The device was opened when its tip lay in the trachea. A standard Portex plastic 8 mm cuffed tracheostomy tube, mounted on an obturator, was then inserted through the jaws. Correct placement of the tube was verified by clinical signs and a later chest X ray.

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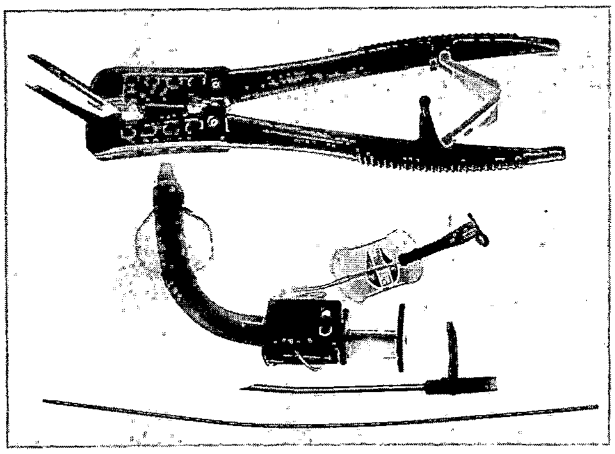

Fig. 1. The 'Rapitrach' kit, which comprises a 12 gauge needle, short guidewire, obturator (inside standard Portex 8 mm tracheostomy tube) and dilating forceps (shown in partly open position).

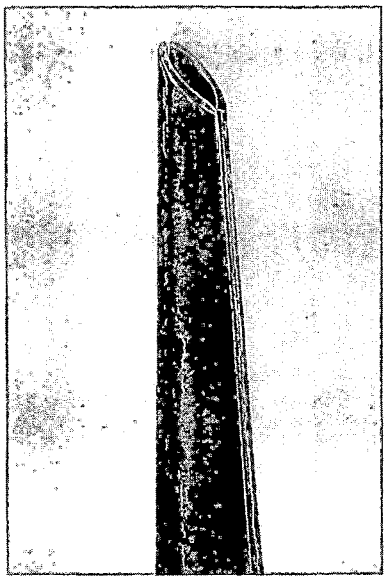

Fig. 2. Close up of jaws of 'Rapitrach'.

Results

The procedure was performed in 20 patients. Their mean age was 54 years (range 21–81). The mean duration of tracheal intubation before tracheostomy was 10.6 days (range 4–16). This unit has no neurosurgical referrals and the majority of patients had multiple organ failure with difficulties in weaning from assisted ventilation. Two patients had a coagulopathy. Platelets or fresh frozen plasma were given immediately before the procedure in these patients, as indicated by coagulation studies. Three patients had severe hypoxaemia (requiring $F\text{IO}_2$ greater than 0.8 to maintain $P\text{aO}_2$ greater than 8 kPa).

The procedure was successful in terms of correct tube placement in all 20 cases. All were elective procedures. The procedure was performed in the ITU in 19 patients. All were performed under the direct supervision of one of four senior anaesthetists. No adult patient who required tracheostomy was considered unsuitable for a dilational technique in the 6-month study period. A number of patients had tracheostomy performed with an alternative dilational technique during the 6-month period because of the experience of individual operators.

One patient with chronic obstructive airways disease, a referral from chest physicians, had not received care on the ITU. The tracheostomy was performed in the operating theatre as the patient was undergoing a procedure to establish long-term venous access. He had undergone conventional tracheostomy 8 months previously, and it had been allowed to close subsequently. The 'Rapitrach' device was passed through the healed stoma without difficulty.

Significant bleeding (defined as blood loss greater than 50 ml) occurred in one patient but the bleeding ceased on insertion of the tracheostomy tube. In two cases the forceps were opened in front of the trachea but there were no adverse sequelae; successful tube placement was achieved in both cases on a second attempt. In two cases, the cuff of the tracheostomy tube was perforated on the jaws of the forceps, necessitating a change of tube in the first few minutes.

Discussion

We have confirmed that percutaneous tracheostomy using this technique may be performed safely at the bedside in the ITU. The procedure is cost-effective and avoids the necessity of transferring unstable patients to the operating theatre.

Older illustrations demonstrate that little in medicine is truly new (Fig. 3). However, the advent of guidewire techniques has provided better control over such instrumentation. The timing [3] and indications for tracheostomy in the critically ill are in many ways more controversial than differences in surgical technique and this is likely to continue to be the case.

A number of different percutaneous tracheostomy techniques have been developed over the last 5 years but most reports concern the use of two techniques described by American and Israeli surgeons [1, 4]. Other devices [5] have not been reported as widely. These techniques allow insertion of a conventional 8 or 9 mm internal diameter cuffed plastic tracheostomy tube below the cricoid cartilage via a small 1–2 cm skin incision. The 'Rapitrach' kit is available in different sizes for the insertion of 6, 6.5, 7, 7.5, or 8 mm tracheostomy tubes.

Our experience of such procedures is favourable but we would advise nonsurgeons to enlist surgical advice and help for the first few procedures as inevitably there is need for surgical assistance on occasions. We performed early procedures, using an alternative technique, in the operating theatre with surgeons standing by.

We have opened the 'Rapitrach' device anterior to the trachea without complications but there has been a recent

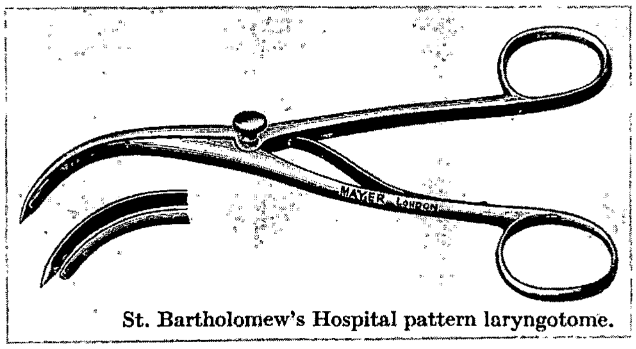
MAYER & LONDON
St. Bartholomew's Hospital pattern laryngotome.

Fig. 3. A tracheotome from the past.

report [6] of two patients in whom complications occurred on dilation of the trachea. In one, the posterior wall of the trachea was split and required surgical repair. The other patient developed a tension pneumothorax. The manufacturers are considering modification of the jaws of the device to improve safety. The use of an instrument similar in principle to the 'Rapitrach' but with more rounded jaws has been described [7].

The safety of these techniques is likely to be operator-dependent but needs to be compared with conventional techniques on any one unit rather than in isolation. Caution in the use of percutaneous techniques has been advised in a recent editorial [8] which also pointed out that much of the information regarding complications of tracheostomy is out of date and requires reassessment. The longer term incidence of tracheal stenosis following dilational techniques remains unknown. Current views on the aetiology of this complication suggest that it should not be any more frequent after dilational techniques than after conventional techniques. Experimental work in dogs [9] supports this argument. The relatively small number of cases to date and the poor long-term survival of patients who require tracheostomy in ITU have delayed the appearance of such clinical data.

In our series we have been impressed by the minimal bleeding, even in patients with a coagulopathy. The avoidance of sharp dissection with dilational techniques may be of particular advantage in this group of patients. Continued bleeding from the tracheostomy stoma can cause life-threatening airway obstruction in some cases. The dilated stoma fits tightly around the tracheostomy, and this helps to control bleeding by tamponade.

The use of dilational techniques for reformation of a healed tracheostomy is controversial. We have used both the 'Ciaglia' and 'Rapitrach' kits successfully in such cases but the anatomy may be distorted, with lateral structures pulled into the midline, and there is an increased hazard of bleeding from major vessels.

It was anticipated that the early changing of tracheostomy tubes might be difficult after dilational techniques, due to the small diameter of the dilated tract. We have not found this to be a problem in practice. The dilated tract appears stable due to the lack of dissection of tissue layers. However, we have not used the technique in patients who rely solely on a tracheostomy for their airway (i.e. those who have complete airway obstruction above the stoma or are likely to present significant difficulties on attempted oro/nasotracheal intubation).

The 'Rapitrach' technique may be performed under local anaesthesia alone, by infiltration of tissue layers and cricothyroid injection. However, we have performed the technique only on patients who were anaesthetised, intubated and mechanically ventilated. The design was intended originally for emergency use [1]. The single-step dilation which is achieved when the jaws of the 'Rapitrach' are opened is considerably quicker than the use of the serial dilators in the 'Ciaglia' kit. This speed may be an advantage when the procedure is performed in patients who require a high inspired oxygen concentration to prevent hypoxaemia.

Dilational techniques have replaced conventional surgical techniques for the provision of elective tracheostomy in critically ill patients in our ITU. We have received requests to perform tracheostomy in patients with respiratory problems outside the ITU. The ease of the technique has refocused attention on the potential advantages of tracheostomy over prolonged oral/nasal intubation.

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Nosocomial sinusitis in ventilated patients

Nasotracheal versus orotracheal intubation

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Summary

A total of 68 postoperative patients whose lungs were ventilated for more than 4 days were studied prospectively during a one-year study period to investigate the effect of the mode of intubation on the paranasal sinuses. After an initial X ray of the skull showing no pathological findings, patients were assigned randomly to one of the study groups; the lungs of patients in group A were ventilated via an orotracheal tube (n = 32), and patients in group B via a nasotracheal tube (n = 36). X ray examinations of the sinuses were performed at regular intervals. Diagnosis of sinusitis was confirmed by transantral needle puncture and culture of fluids obtained. Antibiotic regimens were altered according to laboratory testing. Two patients in group A developed signs of sinusitis in comparison to 15 patients in group B (p < 0.01). However, there were significantly more airway complications in the orotracheal group, particularly during the period of weaning from ventilation. We conclude that orotracheal intubation should be preferred as the routine route of intubation.

Key words

Equipment; tubes, tracheal, tracheostomy.
Intubation; tracheal.
Complications; nosocomial infection, sinusitis.

Nasotracheal intubation is often preferred to orotracheal intubation in patients who require long-term ventilation because of easier fixation of the tube and improved oral hygiene. Although there are many studies investigating the laryngotracheal complications due to nasotracheal intubation [1–9], recent concern has focused on paranasal problems [10–31]. Paranasal sinusitis during mechanical ventilation has been found to be an important cause of nosocomial infection and a source of sepsis [11,17].

The aim of our study was to compare the incidences of sinusitis associated with orotracheal and nasotracheal intubation. In addition, the frequency of complications associated with each route of intubation was investigated.

Patients and methods

Study groups

During the one-year study period from 1 October 1989, 68 patients who required mechanical ventilation in the postoperative Intensive Care Unit (ICU) of the Department of Anaesthesiology, University of Heidelberg, were included in this prospective study. Approval by the local ethics committee was obtained before the beginning of the study.

Patients were not studied, if, on admission, they presented any pathological radiological findings in the sinuses e.g. due to trauma, if they showed any sign of infection, if they were under 18 years of age, or if they received immunosuppressive drugs, and, later on, if their lungs were ventilated mechanically for less than 4 days. Patient care followed the normal protocol of our institution.

All patients were transferred from the operating theatre to the ICU with an oral tube in place. Study patients were then allocated randomly to one of two groups. In group A, orotracheal intubation (OT, internal tube diameter 8 mm, Rüsch Co., Waiblingen, Germany) was continued. In group B, nasotracheal intubation (NT, internal tube diameter 7.5 mm, Rüsch Co., Waiblingen, Germany) was achieved within 6 h of admission. Before nasotracheal insertion of the low pressure–high volume cuffed tube, the naso- and oropharyngeal cavity was flushed completely with a solution of beta-iodine (Braunol, Braun Co., Melsungen, Germany). Thereafter, 5 ml of 0.1% oxymetazoline hydrochloride (Nasivin, Merck Co., Darmstadt, Germany) was injected into each nostril to induce vasoconstriction and to reduce local bleeding. Tubes were not changed routinely after primary insertion. All patients had a nasogastric tube in place for enteral feeding following surgery.

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Diagnostic procedures

Screening for sinusitis was carried out in all patients with the help of bedside antero-posterior X ray examination of the skull ('reversed' Waters' view) on admission, on the 4th, 7th and 10th postoperative days and thereafter at weekly intervals. The X rays were evaluated by an experienced radiologist who was not involved in this study. Patients were examined according to the standard procedures of our department until discharge from the ICU or death. All the patients were followed routinely for clinical evidence of infection. Patients who developed signs of infection with no apparent source were submitted to thorough diagnostic investigations including a CT scan of the head (Fig. 1).

Diagnosis of sinusitis was suspected if the X ray examination showed opacification of the sinuses or air–fluid levels. Diagnosis of sinusitis was made if there were positive radiological signs associated with infection e.g. leukocytes $> 15 \times 10^{9}.1^{-1}$ and fever $> 38.5°C$, and confirmed by transantral maxillary sinus needle puncture with subsequent culture of at least one pathological micro-organism. Culture of the fluid recovered by transantral puncture and drainage was performed and pathogens identified according to standard microbiological procedures.

Therapeutic approach

If purulent sinusitis was present, the sinus was drained by insertion of a silicone tube in the inferior meatus, and a tracheostomy was performed if the patient showed persistent signs of infection within 24 h.

Results were compared using the Chi-squared test with Yates' correction. A p value of < 0.01 was considered to be significant.

Results

Patient characteristics

Patients in groups A and B were similar in respect of age, sex, severity of illness (Simplified Acute Physiological Score (SAPS) [32]), duration of mechanical ventilation, stay in the ICU and mortality (Table 1).

Table 1. Study population. Data are presented as mean (SD) or percentage of total in group.

	Group A (OT) (*n* = 32)	Group B (NT) (*n* = 36)
Mechanical ventilation; days	12.1 (9.5)	10.9 (8.7)
Stay in ICU; days	16.8 (8.3)	15.2 (7.5)
SAPS	12 (4.5)	13 (3.5)
Age; years	62.8 (10.7)	65.1 (9.8)
Sex; male/female	24/8	28/8
Mortality	31.2%	27.7%

OT, orotracheal intubation: NT, nasotracheal intubation; SAPS, Simplified Acute Physiological Score.

Rate of nosocomial sinusitis

During the observation period 15 patients in group A (orotracheal intubation) and 25 patients in group B (nasotracheal intubation) developed radiological signs of sinus infection. A suspected diagnosis was confirmed by sinus needle aspirate and culture in two patients in group A and 15 in group B ($p < 0.01$, Chi-squared analysis; Table 2 and Fig. 2).

Table 2. Incidence of sinusitis.

	Group A (OT (*n* = 32)	Group B (NT) (*n* = 36)
Positive radiological findings	46.8%	69.4%
Sinusitis	6.3%	41.6%

For abbreviations see Table 1.

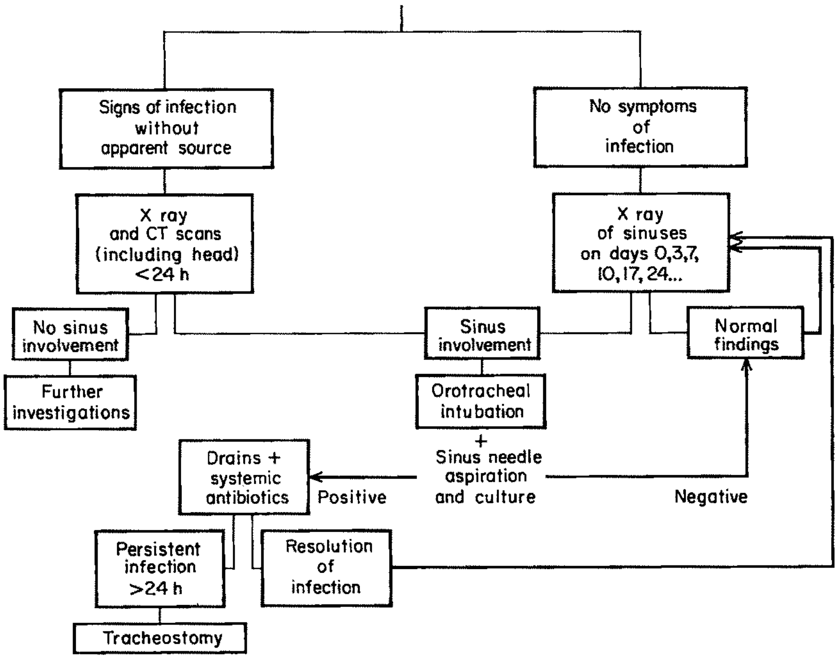
Signs of infection without apparent source
No symptoms of infection
X ray and CT scans (including head) <24 h
X ray of sinuses on days 0,3,7, 10,17,24...
No sinus involvement
Sinus involvement
Normal findings
Further investigations
Orotracheal intubation
+
Sinus needle aspiration and culture
Drains + systemic antibiotics
Positive
Negative
Persistent infection >24 h
Resolution of infection
Tracheostomy

Fig. 1. Flow chart showing plan of investigations and treatment of patients who entered the study.

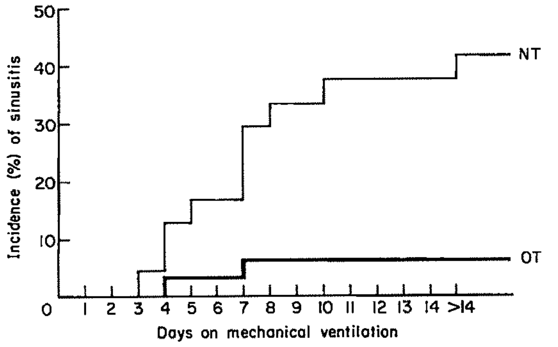

Fig. 2. Cumulative incidence of sinusitis. OT, orotracheal intubation; NT, nasotracheal intubation.

Site of sinusitis

In the orotracheal group, the two cases of sinusitis occurred on the side of insertion of a nasogastric tube. In the nasotracheal group, 10 of the 15 cases were found to be on the side of nasotracheal intubation, two were on the side of the nasogastric tube, and three were bilateral. In group A, the maxillary sinuses were affected in both patients. The involvement of the sinuses in group B is shown in Table 3.

Bacteriological findings

Tracheal aspirates were obtained in all patients twice a week. Culture and identification of isolated micro-organisms followed standard microbiological methods. Sinus aspirates were obtained in 40 patients who showed abnormal X ray findings. The procedure was performed under sterile conditions after cleansing the anterior nasal cavity with povidone–iodine solution to avoid contamination. In 17 cases the fluid was found to be purulent, and specimens were cultured immediately. Isolation of one pathogen occurred in 13 cases; more than one pathogen was isolated in four patients. The pathogens identified are shown in Table 4. In patients receiving antibiotic drugs which were found not to be effective against the pathogen isolated, the antibiotic regimen was altered according to *in vitro* testing.

Incidents related to ventilation

Six incidents which required emergency treatment occurred in the orotracheal group, all during the period of weaning from the ventilator; self-extubation required immediate re-intubation in three patients, unilateral bronchial intubation with subsequent atelectasis occurred in two patients and

Table 3. Site of sinus involvement in patients with sinusitis.

	Group A (OT)	Group B (NT)
Maxillary sinus	2	7
Frontal sinus	0	2
Maxillary and frontal sinuses	0	4
Ethmoid, maxillary and frontal sinuses	0	1*
Sphenoidal, maxillary and frontal sinuses	0	1*

* Results of CT scans. For abbreviations see Table 1.

Table 4. Micro-organisms isolated from sinus and tracheal aspirates.

	Sinus	Trachea
Orotracheal tube		
Patient 1	*Ps. aeruginosa*	*Ps. aeruginosa*
Patient 2**	*Staph. aureus*	*Staph. aureus*
Nasotracheal tube		
Patient 1**	*Ps. aeruginosa*	*Ps. aeruginosa*
Patient 2**	*Staph. epidermidis*	Sterile
Patient 3	*Morganella marganii*	*Ps. maltophilia**
Patient 4	*E. coli*	*E. coli* *Klebsiella pneumoniae*
Patient 5	*Citrobacter*	*Citrobacter*
Patient 6**	*Acinetobacter* *Ps. aeruginosa*	*Ps. aeruginosa*
Patient 7**	*Enterococcus*	*Enterococcus* *Staph. epidermidis*
Patient 8	*Candida albicans**	*Candida albicans** *Staph. epidermidis*
Patient 9**	*Ps. aeruginosa*	Sterile
Patient 10	*Ps. maltophilia**	*Ps. maltophilia**
Patient 11	*Serratia marcescens*	*Serratia marcescens* *Ps. aeruginosa*
Patient 12**	*Klebsiella oxytoca*	*Klebsiella oxytoca*
Patient 13**	*Acinetobacter*	*Acinetobacter*
Patient 14	*Staph. epidermidis*	*Enterococcus**
Patient 15	*Candida albicans**	*Candida albicans** *Staph. aureus*

* Not sensitive to the antibiotic given at time of diagnosis.
** Patients not treated with systemic antibiotics at the time of diagnosis.

hypoxaemia occurred in one patient who bit the tracheal tube. One patient in group B suffered extubation due to inadequate fixation. The frequency of incidents was significantly higher in the orotracheal than the nasotracheal group.

Response to therapy

In 13 patients with confirmed diagnosis of sinusitis, symptoms resolved after orotracheal intubation, systemic antibiotic treatment, and local irrigation with sterile saline via sinus drains. Tracheostomy led to the resolution of infective symptoms in two patients in group B. In two other patients in group B, the same organism was isolated in tracheal aspirate and peripheral blood. These two septic patients recovered from this episode, one after tracheostomy was performed because of nasal ulceration. In all other patients, blood cultures remained negative despite clinical signs of septicaemia in some patients. Ten patients in each group died of other causes such as multiple organ failure in the later course of the ICU stay.

Discussion

In patients receiving long-term mechanical ventilation, nosocomial sinusitis is a serious but underestimated complication which is associated particularly with prolonged nasotracheal intubation [10–31]. The incidence ranges from 100% [22] to 1.4% [23] according to the patient population and the definition of sinusitis. Sinusitis may lead to severe complications, e.g. meningitis, pneumonia and septicaemia [19,25,26].

Under normal conditions, the maxillary sinuses are sterile and well drained by constant mucociliary activity. Obstruction of the ostia due to local swelling may predispose to mucosal oedema, retention of secretions and infection. Occlusion of the sinus openings and blockage of sinus outflow through the nasal ostia by a large-bore tracheal tube is thought to be a main pathogenic factor for sinusitis in ICU patients [23,33,34]. Thus, either the normal flora of the sinuses or colonising hospital-acquired organisms become pathogenic.

In the ventilated and sedated patient, the usual clinical symptoms of sinusitis (e.g. facial pain, headache and local swelling) are frequently absent. Purulent nasal discharge may be a leading symptom. The diagnosis can be made only by a combination of radiological examination (bedside radiography, CT scan), microbiological cultures, and clinical symptoms of infection [30,34–37].

Radiological signs of sinusitis (mucosal thickening, opacification of the spaces, or air–fluid levels in the sinus cavity) are nonspecific and a common finding in mechanically ventilated patients irrespective of the mode of intubation [35,36]. These signs do not necessarily imply a bacterial infection of the sinus cavity although radiographic signs of mucus retention may be precursors of infection [24,27,34]. The same applies to ultrasound examination of the sinuses; findings suggesting sinusitis are found in over 60% of all intubated patients [20,30,31].

The reversed Waters' view seems to be adequate for the diagnosis of maxillary sinusitis [26,35], with the maxillary cavities being affected in most cases [19]. CT scans are superior in the investigation of sinuses other than the maxillary or frontal, e.g. ethmoidal sinuses [19,27,37]. However, this procedure requires transportation of critically ill patients and this has inherent risks.

Bacteriological samples could be contaminated by nasal flora. Cleaning the nares with an antiseptic instillation before puncture and drainage may reduce this risk [12]. In our patients, we observed colonisation and infection of the sinuses and the lungs mostly by the same micro-organisms. This finding confirms the findings of other authors [19,25,26].

The safe duration of tracheal intubation is difficult to define. Recent surveys show a wide variety of common practices and a growing tendency towards prolonged tracheal intubation for up to 3 weeks [9,38]. Late laryngeal lesions and incidents of airway problems are more common with orotracheal intubation. Nasotracheal intubation leads to a higher incidence of local bleeding, local trauma, ear infections, and bacteraemia. Fixation of an orotracheal tube requires meticulous attention to avoid pressure-induced sores and accidental extubation. The indication for prolonged nasotracheal intubation instead of orotracheal intubation and/or tracheostomy should be considered carefully [3–9,27].

A suspected diagnosis of sinusitis (clinically or radiologically) should be confirmed by puncture of the sinuses concerned and by subsequent culture of the aspirate [19,23,26]. The nasotracheal tube should then be changed in favour of an orotracheal tube. Subsequent surgical drainage should be performed, and some authors recommend tracheostomy [26,30]. Systemic antibiotic treatment should be initiated, or altered according to laboratory results [34].

In our department, nasotracheal intubation within 72 h after admission had been routine procedure for long-term mechanical ventilation. The trachea remained intubated for up to 4 weeks before a tracheostomy was considered. Our routine has now changed; patients who require mechanical ventilation for longer than 4 days are left with an orotracheal tube. Short-term nasotracheal intubation (< 72 h) is performed only if there are adverse incidents during the weaning period. Otherwise, a tracheostomy is preferred.

All nasal tubes should be removed and systemic antibiotics should be applied in any patient in whom sinusitis is diagnosed. Sinus drains are inserted and irrigated with a sterile solution of saline. Tracheostomy and surgical drainage of the sinuses are carried out only if the symptoms of infection persist for more than 24 h after changing to an oral tube.

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CASE REPORTS

Neurological sequelae in children after prolonged propofol infusion

C. TROTTER AND M. G. SERPELL

Summary

Neurological sequelae occurred in two children after the withdrawal of an infusion of propofol administered during admission to the Intensive Care Unit for respiratory tract obstruction.

Key words

Anaesthetics, intravenous; propofol.
Complications; neurological.
Intensive care.

Propofol infusions have been used as part of anaesthetic techniques for a variety of surgical procedures, with mean infusion rates in the range of 6.2–15.6 $mg.kg^{-1}.h^{-1}$ [1–4]. Propofol has also been used successfully in the Intensive Care Unit (ICU) for rapid control of depth of sedation. Infusion rates of about 3 $mg.kg^{-1}.h^{-1}$ in patients in ICU have allowed rapid awakening on discontinuation of the infusion after periods of up to 4 days [5, 6]. Younger patients appear to require larger doses both for induction and maintenance of anaesthesia (50% and 25% respectively) compared with adults [3, 7].

Case histories

Case 1. A 4-year-old boy was admitted to another hospital with stridor secondary to a presumed viral infection of the upper respiratory tract. His trachea was intubated and he was sedated with midazolam before being transferred to the ICU at this hospital.

On arrival he was restless despite administration of intravenous boluses of midazolam, and an infusion of propofol was started. This infusion was continued for 4 days (Table 1). When the infusion was discontinued he developed abnormal movements which were thought to be grand mal convulsions. These movements continued despite treatment with diazepam, chlormethiazole, phenobarbitone, phenytoin and paraldehyde. They consisted of fine twitching movements of the muscles of his face, head and shoulders, and also occurred distally in both arms and legs. He was able to open his eyes spontaneously and to follow his mother's movements. He was unable to swallow saliva and appeared to have generalised muscle weakness. His arms and legs were flaccid with depressed reflexes and he required mechanical ventilation for the next 4 days. He received no further sedation apart from the anticonvulsant therapy, which was discontinued after 3 days when there was no further evidence of epilepsy.

Seven days after propofol had been discontinued, muscle power and tone were normal although he had developed exaggerated tendon reflexes and ankle clonus. He was noted to be ataxic when he was strong enough to walk.

The child was anaesthetised with halothane to assess the larynx after the trachea had been intubated for 2, 9 and 12 days but on each occasion he developed stridor on emergence from anaesthesia and required re-intubation. On the 9th day of intubation his larynx looked slightly inflamed and he appeared to have a vocal cord palsy. Bronchoscopy was normal. His trachea was extubated successfully on the 14th day after admission.

Diagnoses of encephalitis, metabolic disorder, peripheral or autonomic neuropathy, and some form of reaction to propofol were considered. The cause of his neurological signs remained unresolved. There were no abnormal findings on examination of serum electrolytes, glucose, ammonia, magnesium and calcium concentrations. Urinary amino and organic acids and porphyrins were also absent, and the CSF was normal. A cranial computerised tomogram scan was unremarkable.

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Table 1. Dose of propofol administered ($mg.kg^{-1}.h^{-1}$) and duration (h) on each day.

	Case 1 (15 kg)		Case 2 (14.5 kg)	
Days	Dose administered ($mg.kg^{-1}.h^{-1}$)	Duration (h)	Dose administered ($mg.kg^{-1}.h^{-1}$)	Duration (h)
1	6	22	9.5	12
2	10.1	24	10.8	24
3	13.2	24	18.1	13
4	10.6	24		
5	8.3	2.5		

He was discharged home 18 days after his admission, with only mild ataxia and some residual twitching of his fingers. He has subsequently made a complete recovery.

Case 2. This 2.5-year-old boy was admitted with severe laryngotracheobronchitis. His trachea was intubated during anaesthesia with halothane. He was then sedated with propofol at an infusion rate of 100 $mg.h^{-1}$. He required increasing doses in order to tolerate the tracheal tube (Table 1). He was noted to be restless and jittery after 44 h and mechanical ventilation was instituted in order to reduce his requirements for sedation. No reduction was possible and the infusion was stopped. The child was taken to the operating theatre for a trial of extubation, but required re-intubation.

On return from the operating theatre he was sedated using an infusion of midazolam 0.2 $mg.kg^{-1}.h^{-1}$ while breathing spontaneously. Twelve hours after the propofol had been discontinued the child was noted to have developed fine twitching movements in his hands and feet, and there were choreiform movements of his arms.

He appeared to be conscious, and eye movements were normal, but he had generalised muscle weakness. The administration of midazolam was stopped and he received no further sedation. His trachea was extubated successfully on the 5th day after admission, by which time his neurological signs were improving, although cogwheel rigidity had developed in his arms. The twitching persisted during sleep but all abnormalities had disappeared completely by the time of his discharge home 9 days after admission.

Serum biochemistry was normal, as were nerve conduction studies.

Discussion

Although propofol was not licensed for use in children in the Intensive Care Unit at the time of writing, it has been used on occasions to provide sedation in this and other hospitals.

The requirements for sedation are high in patients who are young, fit, intubated and not paralysed. The doses of propofol given to our two patients were initially within the conventional range for sedation, but in both cases frequent boluses were required, which, together with a gradual increase in infusion rate, resulted in a high total dose being administered. At no time was there evidence of cardiovascular depression, but in both children muscle weakness seemed to be a feature.

The pharmacokinetic data on propofol in children indicate that higher relative doses than in adults are required to maintain sedation. Larger doses are required also if propofol is used as sole agent compared to its use in combination with opioids [3, 7, 13].

The volume of emulsion administered exposed the children to a large lipid load, but we can find no reference to any neurological syndrome produced in patients due to large doses of lipid emulsion.

Several types of neurological dysfunction have been reported after the use of propofol. These include 'seizures', delayed recovery, opisthotonus and dystonic and choreiform movements [8–10]. Controversy surrounds the possible association between propofol and epileptogenic activity because the drug is known to reduce seizure length during electroconvulsive therapy and has been used successfully to treat status epilepticus [11].

Spontaneous movements are a relatively common side effect during induction of anaesthesia with propofol, especially in children [12]. They are dystonic and choreiform in nature and are not associated with cortical epileptic activity, which suggests a subcortical origin [10]. Borgeat *et al.* [10] reported a reduced incidence of these movements with an increased induction dose of propofol. They postulated that propofol may have an additional inhibitory effect or a central muscle relaxant effect at higher tissue concentrations.

Propofol is cleared rapidly from the blood, but its total elimination is constrained by a slow return from the deep compartment [13]. Significant concentrations may persist for some time within the nervous system, producing effects which depend on the balance between effects on inhibitory and excitatory neurones.

There has been recent correspondence about the possibility of a propofol withdrawal syndrome [14, 15]. A report by Imray *et al.* of a child with a similar picture of generalised twitching adds further weight to the suspicion of a withdrawal syndrome [16].

We have reported these cases to both the Committee on Safety of Medicines and the manufacturers. Both children made a complete recovery, but until the situation becomes clearer we shall not be using propofol as the sole agent for sedation in children in the ICU.

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APPARATUS

Resistance and additional inspiratory work imposed by the laryngeal mask airway

A comparison with tracheal tubes

S. B. BHATT, A. P. KENDALL, E. S. LIN, AND T. E. OH

Summary

Laryngeal mask airways and tracheal tubes were studied to determine both their resistance to constant gas flows and additional inspiratory work during simulated inspiration. Laryngeal mask airways imposed less resistance and required lower additional inspiratory work compared with the corresponding sized tracheal tubes. If inspiratory loading during anaesthesia is an important consideration, then the laryngeal mask airway may be preferable to a tracheal tube.

Key words

Equipment; laryngeal mask, tracheal tube.
Airway; resistance.

The laryngeal mask airway (LMA) has recently been introduced into clinical practice as an alternative means of maintaining the airway during anaesthesia. Since its introduction it has gained widespread popularity and has been used in a variety of clinical situations [1, 2]. It is relatively easy to use and may have advantages over a conventional tracheal tube. For example, an LMA can be used in patients who are difficult to intubate [3], and laryngeal injury associated with tracheal intubation may be avoided. The cardiovascular response to LMA insertion is less than that associated with laryngoscopy and tracheal intubation [4, 5]. Also the LMA frees the anaesthetist's hands for performing other tasks.

Despite a host of reports on the clinical use of the LMA, little is known of its interaction with the patient's respiratory system. The LMA has three vertical bars within its lumen at the patient end. These are designed to prevent the epiglottis from obstructing the lumen, but may impede gas flow and lead to increased resistance to breathing. With this in mind, we studied the resistance and additional inspiratory work imposed by the LMA in comparison with tracheal tubes.

Material and methods

The resistances of LMAs sizes 1–4 and tracheal tubes (Portex, Kent, UK) sizes 4–9 mm internal diameter (ID) were studied under conditions of constant gas flow and simulated inspiration. All measurements were made using dry air at room temperature. Air flow was measured using a Fleisch no. 2 pneumotachograph (Instrumentation Associates, NY, USA) coupled with a sensitive pressure transducer (MP 45-1, (SD 2) cmH_2O Validyne Engineering, Northridge, Ca, USA). Pressure measurements were made using a calibrated Gaeltec 8T 50 differential pressure transducer (Medical Measurements Inc., NJ, USA) which was linear between 0–50 cmH_2O. The pressure and flow transducers were calibrated using an RT 200 calibration analyser (Timemeter Corp, PA, USA). Pressure and flow signals were displayed and recorded on an oscilloscope (DSO 1604, Gould Electronics Ltd, Essex, UK). Digitized data at 200 samples.s^{-1} were then processed using an IBM computer.

All tracheal tubes were studied with their connectors in place and cut to various lengths, as shown in Table 1. These lengths have been recommended [6] for use in patients according to patient age, and denote the expected distance from lips to mid-trachea. For constant gas flow measurements, a flowmeter was used to pass air through the pneumotachograph and then through the LMA or tracheal tube (Fig. 1(a)). The patient end of the LMA or tracheal tube was interfaced with a model trachea, which was constructed from a transparent plastic hose of 24 mm ID and 10 cm length. The differential pressure between points P1 and P2 was measured (Fig. 1). Point P2 was

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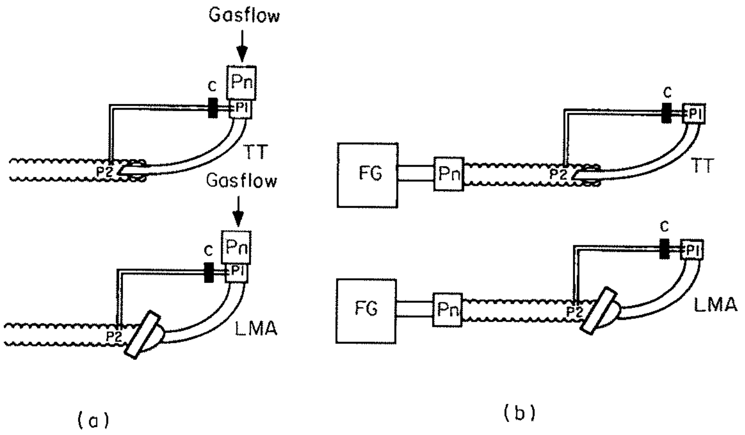

Fig. 1. (a) Tracheal tube and LMA during constant flow, and (b) simulated inspiration experiments. Pn, pneumotachograph, pl and p2, differential pressure measuring sites; FG, flow generator; TT, tracheal tube.

located 10 mm downstream of the patient end of the LMA or tracheal tube and the pressure measuring catheter tip was placed midway between the model tracheal wall and the centre of its lumen. Measurements were made at approximately 2.5 l.min^{-1} increments, from 0–30 l.min^{-1} and thereafter at 5 l.min^{-1} increments up to 60 l.min^{-1}. All measurements were made in duplicate. The means of the two results were used for computing the pressure-flow curves and for the calculation of resistances.

A second order polynomial ($P = K_1 \cdot \dot{V} + K_2 \cdot \dot{V}^2$, where P is the pressure gradient across the tube , $\dot{V}$ is the flow, and K_1 and K_2 are constants) was fitted to the pressure-flow points and appeared to describe the curves adequately. The equation $P = K_1 \cdot \dot{V} + K_2 \cdot \dot{V}^2$ was then solved for flows of 0.5 l.s^{-1} and 1.0 l.s^{-1}. Resistances were deduced according to the relationship: resistance = pressure gradient/flow. The resistances thus calculated were expressed as kPa l.s^{-1} at 0.5 l.s^{-1} and 1.0 l.s^{-1}.

Simulated inspiration studies of additional inspiratory work were performed using a modified Cape TC 50 ventilator (Cape Engineering, UK) as previously described [7]. The LMAs and tracheal tubes were interfaced with the ventilator using the model trachea described earlier. The tracheal tube cuff was inflated to ensure an airtight seal up to a pressure of 20 cmH_2O. A similar airtight seal for the LMA was achieved using an interface attached to the model trachea. The interface for the LMA with the model trachea was made from moulded plastic into which the inflated cuff of the LMA fitted snugly. Inspiration was simulated by the vacuum effect created by the Cape ventilator's expiratory phase [7]. The simulated inspiratory flow during each inspiratory half cycle was an approximate sine wave. The experimental arrangement is as shown in Figure 1(b).

In measuring additional inspiratory work and dynamic pressure flow characteristics, each LMA and tracheal tube was studied at eight different tidal volumes. The tidal volumes studied ranged from 60 ml for LMA size 1 to 850 ml for LMA size 3/4. Tidal volumes were selected across a range considered suitable for the patient population in whom these devices were likely to be used. The respiratory rate was held constant at 15 breath.min^{-1} and the I : E ratio was held constant at 1 : 3. Tidal volume was measured by integrating the digitized flow signal during the inspiratory half cycle. Additional inspiratory work was computed from the pressure : flow recordings according to the method of Engstrom and Norlander [8]. The product of pressure (P) and flow ($\dot{V}$) at a time was used to derive power (W) at that time. Integration of the power curve with respect to time (from the onset of to the end of inspiratory flow) was used to yield work over the inspiratory cycle. Additional inspiratory work was expressed as Joules/breath.

For both resistance and additional inspiratory work studies, the data for each size of LMA was compared with tracheal tubes suitable for use in similar sized patients.

Results

LMAs size 3 and 4 had identical internal diameters and lengths, and yielded similar values for resistance to gas flow. These data were therefore pooled together.

Table 1. Dimensions and resistances of tracheal tubes and laryngeal mask airways under test.

Device under test	Length (cm)	Internal diameter (mm)	Resistance (kPa.l.s^{-1}) at 0.5	Resistance (kPa.l.s^{-1}) at 1.0
Tracheal tube 4	12	4.00	4.84	10.49
Tracheal tube 5	14	5.00	2.12	4.47
Tracheal tube 6	15.5	6.00	0.86	2.1
Tracheal tube 7	18.5	7.00	0.38	1.07
Tracheal tube 8	22	8.00	0.26	0.53
Tracheal tube 9	23	9.00	0.18	0.33
LMA 1	10	6.00	1.16	2.83
LMA 2	12	8.00	0.26	0.45
LMA 3/4	18	11.00	0.1	0.15

Table 2. Patient size recommendations for the use of LMA.

LMA size	Patient size
One	Neonate, 6.5 kg
Two	6.5–25 kg
Three	25 kg, small adult
Four	Normal to large adult

Constant flow experiments—resistance

Typical differential pressure flow curves for the LMAs and tracheal tubes are shown in Figure 2. The LMA size 1 was grouped with a tracheal tube of 4 mm ID, the LMA size 2 with tracheal tubes of 5 and 6 mm ID and LMAs of sizes 3 and 4 with tracheal tubes of 7, 8 and 9 mm ID. These groupings were made according to the manufacturer's recommendations for patient sizes for LMAs (Table 2).

The differential pressure at any flow and the calculated resistances at 0.5 $l.s^{-1}$ and 1.0 $l.s^{-1}$ were less for the LMA compared to the corresponding sized tracheal tube (Fig. 2, Table 1).

Simulated inspiration experiments—additional inspiratory work

The additional tracheal tube and LMA inspiratory work is shown in Figure 3. At any given tidal volume, the additional inspiratory work increased with decreasing tube diameters. Moreover, at any tidal volume, the additional inspiratory work while inspiring through an LMA was less than that measured when inspiration was simulated through the corresponding-sized tracheal tube (Fig. 3). These differences were especially marked when larger tidal volumes were studied.

Discussion

The present study compared the resistance and additional inspiratory loads imposed by LMAs with the corresponding-sized tracheal tubes.

Previous reports show varied tracheal tube resistances obtained during constant flow experiments [9, 10]. The differences were attributed to the positioning of the downstream pressure measuring catheter [11]. Placement of the downstream pressure measuring catheter in the present study was similar to that of Demers and colleagues [11] and our results for resistance at 0.5 $l.s^{-1}$ and 1.0 $l.s^{-1}$ are comparable to theirs. Demers and colleagues [11] reported the resistance of an 8.0 mm ID tracheal tube at 0.5 $l.s^{-1}$ as 0.37 $kPa.l.s^{-1}$. In the present study the resistance of a similar internal diameter tube was found to be 0.26 $kPa.l.s^{-1}$ at 0.5 $l.s^{-1}$.

Ferguson and colleagues [12] measured airway resistance using body plethysmography with and without inspiration through an LMA and concluded that the resistance offered by the LMA was of the same order of magnitude as a tracheal tube. However, in the present study it was found that the resistance of the LMA during constant gas flow was less than with the corresponding size tracheal tube (Table 1). Ferguson and colleagues do not specify the size of LMA tested and therefore the present results cannot be compared to theirs.

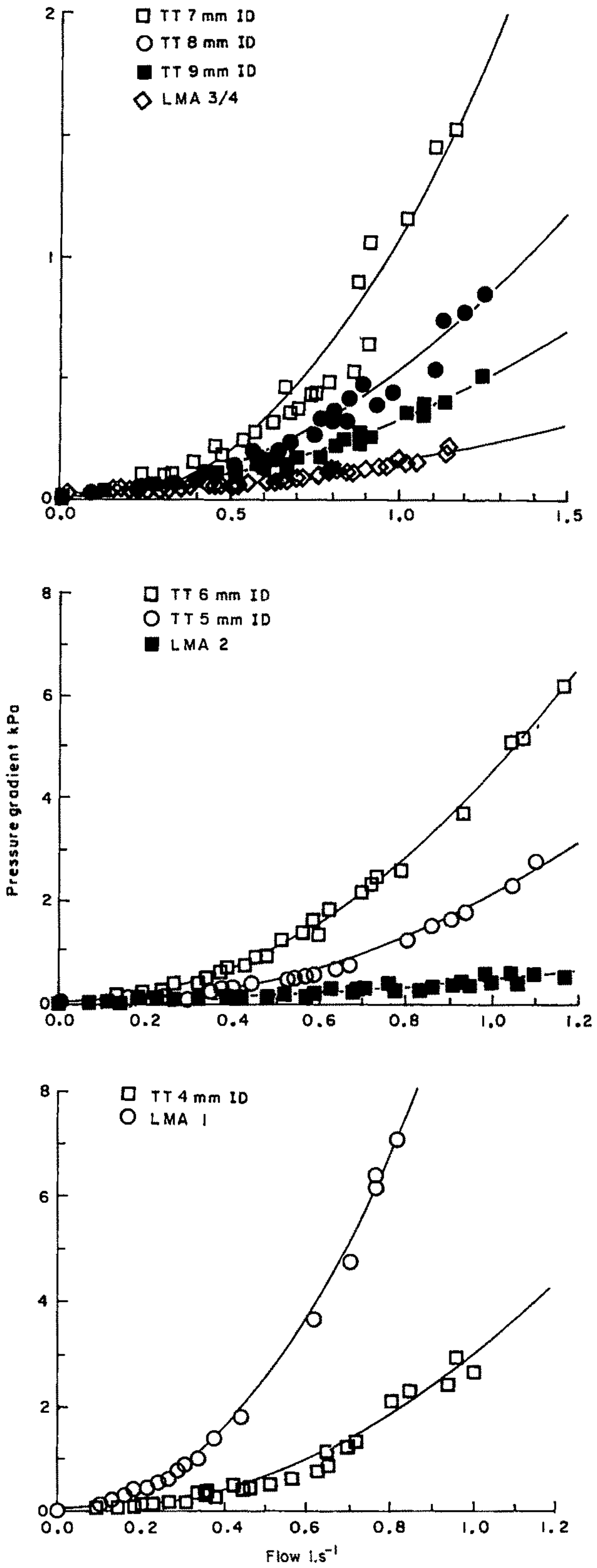

Fig. 2. Pressure flow relationship of tracheal tubes and LMAs during constant flow experiment. TT-tracheal tube.

The LMA's lower resistance, compared to the corresponding-sized tracheal tube, is a reflection of the shorter length, and more importantly, the larger diameter of the LMA. These differences were especially marked when smaller tracheal tubes were compared with the corresponding-sized LMA. For example, the resistance during

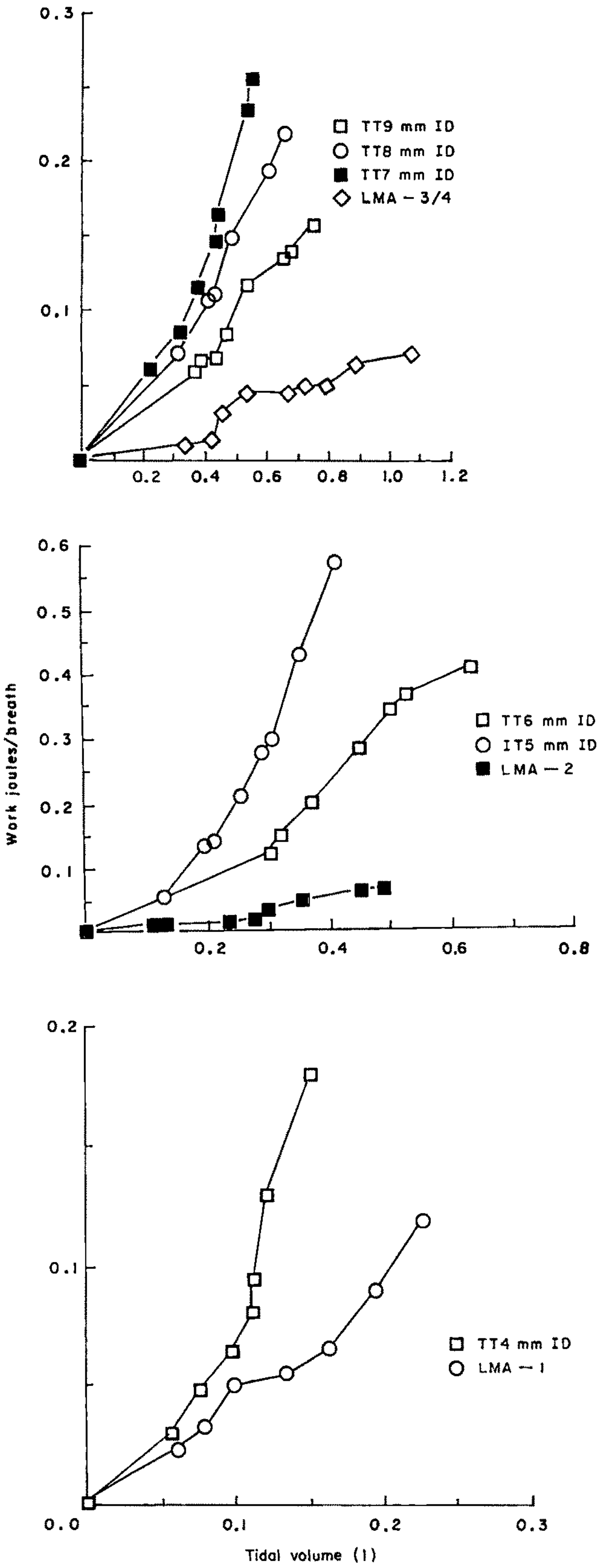

Fig. 3. Work–tidal volume relationship of tracheal tubes and LMAs during simulated inspiration experiment. TT, tracheal tube.

constant flow of a 4 mm ID tracheal tube was found to be 4.84 kPa.l.s.$^{-1}$ at 0.5 l.s^{-1}, while that of the corresponding-sized LMA (size 1) was only 1.16 kPa.l.s^{-1}. However, when LMAs were compared to tracheal tubes of the same internal diameter the LMAs, despite their shorter lengths, appeared to have greater resistance. LMA size 1 with a 6 mm ID had a resistance of 1.16 kPa.l.s^{-1} at 0.5 l.s^{-1}, while that of a tracheal tube with a 6 mm ID, despite its longer length, had a resistance of only 0.86 kPa.l.s^{-1} at 0.5 l.s^{-1}. The three vertical bars at the patient end of the LMA lumen may contribute to this increased resistance.

It has previously been suggested that the additional inspiratory work imposed by tracheal tubes may be a more relevant parameter to study, rather than resistance during constant gas flow [13]. The additional work imposed by tracheal tubes during simulated inspiration has been studied previously [13–15]. Our results for additional work during simulated inspiration are similar to those obtained by Bolder and colleagues [13], who measured additional inspiratory work at frequencies of 6, 12 and 20 breath.min^{-1}. In the present study, we simulated respiration at 15 breath.min^{-1} and our results for additional inspiratory work lie between those obtained by Bolder *et al.* at 12 and 20 breath.min^{-1}. For example they found the additional inspiratory work during a 350 ml inspiration through an tracheal tube 7 mm ID was 0.069 Joules at 12 breath.min^{-1} and 0.138 Joules at 20 breath.min^{-1}. In the present study for a 370 ml tidal volume at 15 breath.min^{-1} we found it to be 0.117 Joules. In addition our results confirm that smaller tube diameters and larger tidal volumes increase the additional inspiratory work. (Fig. 3).

The additional inspiratory work imposed by LMAs has not been previously reported. In the present study, the relative tidal volume/work relationships for tracheal tubes and LMAs appeared to reflect resistance measured during constant flow experiments. Additional inspiratory work imposed by an LMA was considerably less than that imposed by the corresponding-sized tracheal tube. For example, the additional inspiratory work for a 430 ml tidal volume through an 8.0 mm ID tracheal tube was found to be 0.112 Joules, whereas additional work while breathing through an LMA sized 3/4 for a similar tidal volume was 0.012 Joules. Mecklenburgh and colleagues [16] estimated the natural work of breathing for a 500 ml tidal volume to be about 0.2 Joules. Thus, while the additional work imposed by an 8.0 mm ID tracheal tube is of the same magnitude as that expended in overcoming the compliance and resistance of the lungs, the work imposed by a corresponding sized LMA is considerably less.

Increased resistance of breathing systems and the added inspiratory loads imposed, may affect successful weaning from mechanical ventilation [16], in patients recovering from respiratory failure. However, exact consequences of moderate increases in system resistance in an anaesthetised, spontaneously breathing patient are unclear. Nunn and Ezi-Ashi [17] found that during anaesthesia respiratory compensations for added inspiratory and expiratory loading was rapid and complete. Freedman and Campbell [18], on the other hand, presented evidence to suggest that during inhalational anaesthesia, ventilatory responsiveness to added inspiratory loading may be diminished. Despite this difference of opinion, it is a good practice to be aware of the respiratory loading effect of different anaesthetic apparatus and to keep these loads to a minimum. The results of the present study indicate that, on the basis of the added inspiratory load of the two tubes, the LMA may be preferable to a tracheal tube. However, an additional source of inspiratory resistance while using an

LMA may arise at mask–larynx interface. A faulty apposition of the LMA to the larynx would increase resistance and inspiratory work. The methodology of the present experimental study did not address this question.

In conclusion, the resistance during constant flow and additional inspiratory work imposed by the LMA was found to be considerably less than that imposed by the corresponding sized tracheal tube. If a choice is available, then in terms of their inspiratory loading effect, it may be preferable to use an LMA rather than a tracheal tube.

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APPARATUS

Measurement of forces during laryngoscopy

M. J. L. BUCX, P. A. E. SCHECK, R. T. M. VAN GEEL, A. H. DEN OUDEN AND R. NIESING

Summary

The forces transmitted by the laryngoscope blade onto the base of the tongue are assumed to be a major cardiovascular stimulus. This study investigates the various forces applied onto a Macintosh laryngoscope during laryngoscopy. The forces acting along the axis of the handle are described, as well as the forces exerted by the anaesthetist to prevent the laryngoscope from turning. Based on a relatively simple technique, a modified laryngoscope has been designed to measure these forces. Four different laryngoscopic parameters are determined: (1) the duration of laryngoscopy, (2) the maximally applied force, (3) the mean force and (4) the integral of the force over the time (area under the curve). The force measurements of 49 anatomically normal patients undergoing uncomplicated intubation are included in the study. The duration of laryngoscopy was 16.3s (SD 11.8), the applied peak force was 35N (SD 12) and mean force necessary was 20N (SD 6) while the force–time integral was 324N (SD 194).

Key words

Equipment; laryngoscope.
Intubation; tracheal.

Laryngoscopy and subsequent tracheal intubation are known to have profound influence on circulatory parameters and intracranial pressure [1–4]. Forces transmitted by the laryngoscope blade onto the base of the tongue are assumed to be the major stimulus [5–8]. To investigate the relationship between laryngoscopy and intubation stimulus on the one hand and response on the other, the forces applied by the blade of the laryngoscope have to be quantified. Different devices to measure these forces have been described [9–12]. However, these devices were difficult to construct and the measurements obtained were difficult to interpret.

During proper use of the curved blade laryngoscope designed by Macintosh the forces applied to the laryngoscope should be directed parallel to the axis of the handle [13, 14]. The forces applied by the laryngoscope are counteracted by the tissues in contact with the blade (Fig. 1). According to the first law of Newton the tissues exert forces with the same magnitude but with opposite direction. The different mechanical characteristics of the tissues, the curved shape of the blade and the direction of the forces applied to the handle result in a nonhomogeneous distribution of the forces along the blade.

These forces can be analysed by vector analysis. The resulting forces transmitted by the tissues onto the blade (F_T) are characterised by a varying point of application,

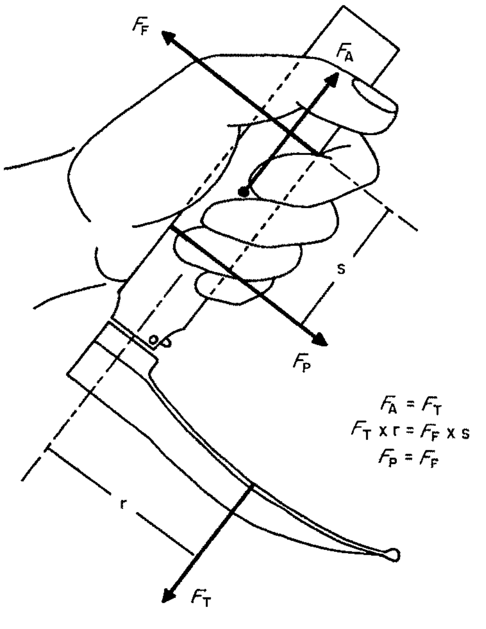

Fig. 1. Hand of the anaesthetist with laryngoscope. The force exerted by the tissues (F_T) with the corresponding moment ($F_T$xr) is shown. The forces exerted by the hand in the axial direction (F_A) as well as the forces exerted by the fingers (F_F) and palm (F_P), to compensate the moments exerted by the tissues, are shown.

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magnitude and direction. Because of the eccentric application point these forces produce a certain moment onto the laryngoscope ($F_T$xr). To prevent the laryngoscope from turning, this moment should be balanced by a counteracting moment exerted by the hand of the anaesthetist. Forces exerted by the palm of the hand (F_P) and the fingers (F_F) account for the overall moment ($F_F$xs).

This model is a simplification of what actually happens. Other forces, such as rotational forces in the plane perpendicular to the handle of the laryngoscope, will be present; moreover, the forces discussed may not be exerted precisely in the optimal direction. However, it is clear that forces parallel to the axis of the handle are the most relevant.

Technical development

Construction of a laryngoscope with a force-sensing device positioned between the handle and the blade appeared a feasible option. However, at this position different forces are present [15, 16] (Fig. 2). There are tensile and compressive forces to counteract the moments resulting from forces exerted on the blade, and there are shearing forces, perpendicular to the axis of the blade. In contrast to the tensile and compressive forces, shearing forces are independent of the application point mentioned above [15]. Moreover, they are independent of the shape of the blade [17].

A strain gauge based sensor to measure shearing forces using strain gauges has been described by Gommers [16]. This device is sensitive in one direction only, with minimal influence of other forces (deviation < 2%) acting at the same location. A clinical application of this sensor has been described [17].

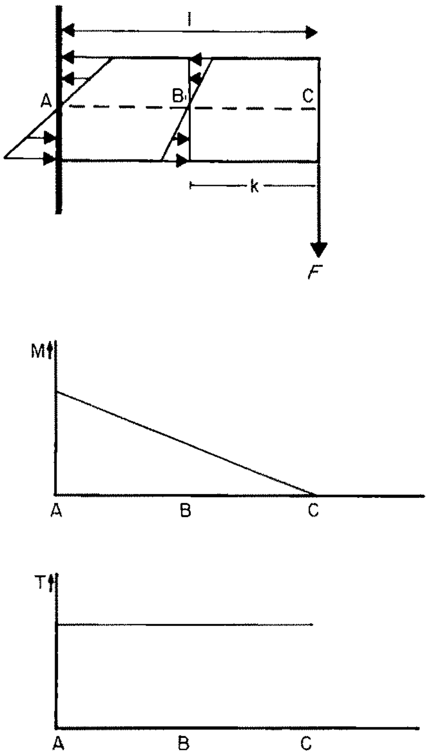

Fig. 2. Schematic representation of the connection between handle and blade with the downward directed force F exerted by the tissues. The moment (M) in A is the product of F and l. The shearing forces (τ) in the beam are constant.

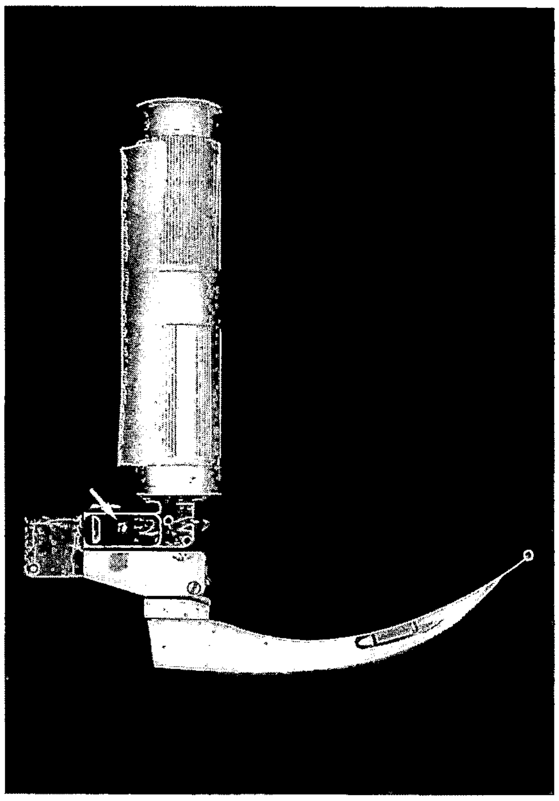

Fig. 3. Laryngoscope enabling measurement of axial forces by strain gauges. The arrow indicates the position of the strain gauges.

This sensor was built into a laryngoscope with a curved blade (Macintosh) enabling only measurement of the force parallel to the axis of the handle. The device has excellent linearity (deviation < 1%) and reproducibility (deviation ≪ 1%). The shape and weight of the handle and blade are similar to those of a conventional laryngoscope, except for the shearing force sensor, protruding backward towards the anaesthetist but causing no inconvenience (Fig. 3). Due to the weight of the blade and the connection to the sensor, the orientation of the laryngoscope has an influence on the measurement. With the handle in the vertical position this influence is zero; with the handle at an angle of 45° to horizontal it is −0.64 N and with the handle in a horizontal position the influence is −2.21 N.

The strain gauges (Measurements Group Inc, Raleigh, NC, USA) are placed in a full electronic bridge and connected to a bridge amplifier with zero calibration and gain adjustment (Peekel Instruments, Strainindicator CA 660, Rotterdam, The Netherlands). The amplifier is connected to a recorder (Hewlett Packard, 7132A, San Diego, CA, USA) for continuous registration. The electrical force signal is integrated over time to determine the 'area under the curve' and the integral is simultaneously recorded.

Calibration to zero is achieved by keeping the laryngoscope handle in the vertical position. No zero drift was observed within a 3 h period. Calibration is performed by simply placing a weight of 2 kg (= 19.6 N) onto the laryngoscope blade, as calibration with additional weights had shown full linearity of the measuring system.

It is thus possible to determine four laryngoscopic parameters: (1) the duration of laryngoscopy (t), (2) the maximally applied force (F_{max}), (3) the mean force (F_{mean}) and (4)

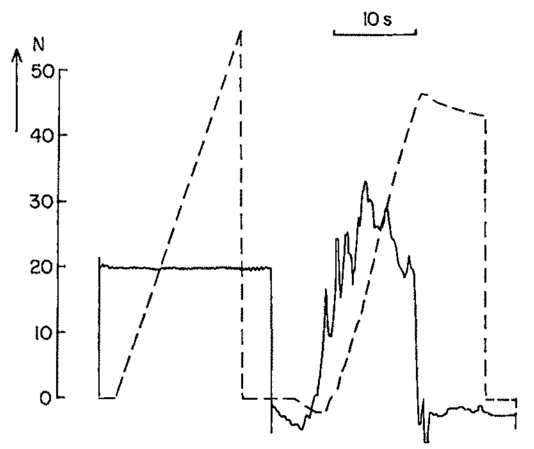

Fig. 4. Forces required in typical patients; the solid line shows the measured shearing force and the dotted line shows the force–time integral. The left part of the figure represents the calibration at 19.6 N (= 2.0 kgf). The deflection just before laryngoscopy is caused by the position of the laryngoscope.

the force–time integral (F*t; area under the curve). In routine practice, the instrument worked effectively.

Patient material

Using the modified laryngoscope, the laryngoscopic parameters were determined in 49 adult patients (ASA 1–2; 22 males, 27 females) scheduled for elective surgery. The study was approved by the Hospital Ethics Committee. Before each measurement the instrument was calibrated as described above. Only patients in whom routine uncomplicated laryngoscopy and subsequent intubation were anticipated were included in the study. Patients in whom intubation proved difficult or was not achieved at first attempt, were excluded. Premedication consisted of intramuscular midazolam 2.5 mg and atropine 0.5 mg given 1 h before induction of anaesthesia. Anaesthesia was induced with thiopentone 4–5 mg.kg^{-1}, fentanyl 2 μg.kg^{-1} and suxamethonium 1.0–1.5 mg.kg^{-1}. Patients' lungs were ventilated with 66% nitrous oxide in oxygen.

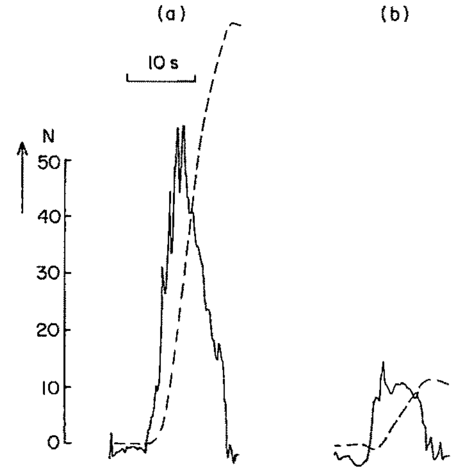

Fig. 5. High (a) and low (b) force requirements. Calibrations are not shown.

Results

The duration of laryngoscopy was 16.3s (SD 11.8) (range 6.8–43.2 s); F_{max} was 35N (SD 12) (range 13–60 N), F_{mean} was 20N (SD 6) (range 9–32 N) and F*t integral was 324N (SD 194) (range 66–981 N). In all patients the view on the glottis was classified as Cormack and Lehane grade I [18].

Data from an uncomplicated intubation is shown in Figure 4, and high and low force requirements in Figure 5(a) and (b).

Discussion

More complicated devices which measure several component forces have been described previously [9], but their use in humans has not been reported. A technique to monitor laryngoscopic pressures on the tissues using a hydrostatic transmitter fixed to the distal part of the blade has also been reported [10, 11]. However, it is difficult to relate these pressures to the forces applied by the blade.

The modified instrument described here has proved to be effective and reliable in measuring forces during routine laryngoscopy. The construction was simple; results are clear and easy to interpret, thus fulfilling the needs of anaesthetists. The device may be particularly useful to study the relationship between applied forces and changes in circulatory parameters, and to compare different blades with respect to the forces necessary to perform intubation. Moreover, the described device could be an important aid in the instruction of laryngoscopic techniques [9].

Acknowledgments

We thank Professor W. Erdmann for critical advice, J.A. de Man for technical assistance, and Laraine Visser-Isles for English language editing.

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Correspondence

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Personal experience of three commonly used methods of postoperative pain relief

There have been some excellent articles recently on postoperative pain relief and pain relief services [1–3]. I have recently experienced three currently used methods at first hand during the first 24 h after a total hip replacement and venture to suggest that my subjective experiences might be of interest to other anaesthetists.

The operation was performed at a well run teaching hospital, whose Anaesthetic Department is renowned for its high standards. I awoke on arrival in the recovery room, clear-headed and pain free after an anaesthetic which consisted of epidural block, with propofol sedation. The epidural catheter was still in place, and attached to a Graseby-2000 pump. A dull pain in the gluteal region was rapidly corrected by adjustment of the pump by my anaesthetist.

I remained comfortable, happy and clear-headed during my 4 h stay in the recovery room and was able to report any side effects to the nursing staff. On two occasions I felt light-headed, and each time my systolic blood pressure was found to have decreased to below 80 mmHg. On one occasion I realised that deep breathing and coughing were becoming difficult and the level of the block has risen to T_4. These side effects were rapidly detected and corrected. I was impressed that it was so easy to report these problems at an early stage.

After 4 h the recovery ward closed for the weekend (it was Saturday afternoon) and I was transferred to my ward. Since the ward nursing staff are not allowed to care for patients with continuous epidurals, the catheter was removed, and a PCA pump attached to an intravenous

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cannula. This was a Graseby 2000, containing morphine 1 mg.ml^{-1}; 1 mg was allowed to be delivered every 10 min at most.

To my surprise the use of this PCA was not nearly as pleasant or effective as I had always supposed it to be. Pain relief was slow in onset and not nearly as adequate as the epidural had been. I became drowsy, dizzy and dysphoric. The worst side effect was the onset of persistent and eruptive vomiting, which was not controlled by prochlorperazine. It was not easy to clear my airway as I could neither sit nor turn sideways; also I was drowsy. I have received opioids postoperatively in the past but never experienced nausea or vomiting with them.

Some hours later, both the infusion and the auxillary cannula for the PCA pump leaked into the tissues (subcutaneous morphine stings!). My veins were not pronounced that evening and the resident orthopaedic surgeon was unable to resite a cannula. My consultant anaesthetist kindly came in from home and managed to resite the infusion after several attempts and with much skill. Only then could the PCA be restarted. By this time an hour or two without the pump must have elapsed and analgesia had worn off completely, but so had the vomiting.

The vomiting increased as the analgesia again took effect. At around 0200 the infusion drip tissued once more and some time elapsed while medical staff were contacted and made the decision to discontinue the infusion that night. This also meant discontinuation of PCA. After further discussion I received simultaneous intramuscular injections of morphine and prochlorperazine. The pain relief was soon superior to that with the PCA; vomiting ceased and I slept. Intramuscular analgesia was administered when needed (about 4-hourly, I believe) and at no time wore off to the extent that the PCA had done; it was far more pleasant.

It is fairly common for cannulae to become misplaced during the first night postoperatively and for time to elapse before resiting. This must be a great disadvantage to the patient if a PCA pump is dependent on the cannula.

I am due to have my second hip replacement in a few months time. My choice of analgesia will in future be: (1) continuous epidural; (2) intramuscular opioids. Before the above experience my first choice was definitely PCA, which I now consider less safe than continuous epidural analgesia in my own case.

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Pre-operative paravertebral block for peri-operative analgesia

A dominant theme in current clinical practice is to improve quality of pain relief after operation, and one of the things that we can all do is to make better use of existing techniques. I would like to report my experiences with paravertebral block in 110 patients. In the presence of unilateral wounds, this technique makes a valuable contribution to patient comfort in the immediate postoperative period, typically reducing pain scores to nil or slight.

Paravertebral block has been dismissed as of historical interest only, but it is regularly employed by our veterinary colleagues. Indeed, a recent photograph in *Anaesthesia News* showed a cow undergoing Caesarean section with a paravertebral block.

The technique I use is that described by Eason and Wyatt [1] and the block is performed after induction of anaesthesia with the patient in the lateral position with the side to be operated on uppermost. For a single-shot technique an 18 gauge Venflon paravertebral block needle is used (Viggo AB, Helsingborg, Sweden). Bupivacaine 0.5% with 1:200000 adrenaline in a volume of 25 ml is used. The injectate spreads laterally into the adjacent space and craniocaudally over the anterior surfaces of the ribs to adjacent paravertebral spaces [2]. In adults, 3–4 segmental nerves can be blocked by this volume. Catheterisation of the paravertebral space using a Tuohy needle and epidural catheter is equally simple, with easy passage of the catheter indicating successful entry into the paravertebral space. Infusion of 0.25% bupivacaine with adrenaline 1:200000 at 5–10 ml.h^{-1} then maintains a moderate sensory block of a somatic wound. Requirement for opioid is often reduced to single or twice daily dosage; greater need suggests failure of the technique.

Over the last 18 months I have made increasing use of unilateral paravertebral block to supplement general anaesthesia in cases where surgery involves a unilateral incision. A single-shot technique is used for procedures such as mastectomy, enterostomy, appendicectomy or inguinal hernia repair. Analgesia usually lasts 4–6 h into the immediate postoperative period. When more prolonged analgesia is required, a catheter technique has been used successfully (in 25 patients to date) for up to 48 h following cholecystectomy, renal surgery and prosthetic hip or knee replacement.

Out of the total of 110 cases receiving paravertebral block, there have been only five technical failures and one occasion when a catheter could not be passed.

Inadvertent intravenous injection occurred on one occasion when a single-shot was performed at the end of surgery during emergence from anaesthesia; a brief convulsion resulted, but subsequent recovery was full. On this occasion plain bupivacaine was used; intravascular injection could possibly have been recognised earlier if an adrenaline containing solution had been used as a test dose. Medial spread into the epidural space is also a possible complication. Clinically evident epidural spread of local anaesthetic, as judged by the presence of bilateral numbness and leg weakness, was seen in four patients.

The versatility and simplicity of paravertebral block suggests that in the presence of a unilateral wound, this technique may offer advantages over epidural block. Following paravertebral block, haemodynamic stability is evident, as pressor responses to surgical stimuli are obtunded yet sympathetic block is limited. Bladder sensation is not lost, and leg weakness does not occur, unless the block is sited at L_{2-4}. In addition, the other potential risks associated with epidural block are minimised.

The good quality of analgesia that results from effective somatic paravertebral block reduces requirement for opioid analgesics and thereby reduces the likelihood of their undesirable side effects, but at the same time promotes early mobilisation, alimentation and ambulation even after operations on the chest, loin or upper abdomen.

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Pattern of use of the laryngeal mask airway

We recently conducted a survey of the use of the laryngeal mask airway (LMA) by 66 anaesthetists within the Cardiff teaching hospitals. Only one anaesthetist considered that the LMA had no role to play in their anaesthetic practice. The LMA was more popular with the senior registrars and registrars than with the consultants; it was also noted that the consultants more readily abandoned insertion of the LMA (8% as apposed to the registrars' 3%). The contraindications to usage of the LMA increased in accordance with the seniority of the anaesthetist. The consultants, as a group, listed eight contradindications: a prone or head-down position, IPPV, risk of regurgitation, risk of bleeding, the use of muscle relaxants, short cases (less than 5 min in duration) and lastly those cases where high airway pressures occur.

The preferred induction technique for insertion of the LMA varied considerably between grades; for example 36% of the consultants and 50% of registrars used propofol alone, whereas no senior registrar used solely propofol. An induction technique, involving a combination of fentanyl and propofol, was used by 65% of senior registrars, compared to respective figures of 32% of the consultants and 43% of the junior registrars.

There was general agreement between grades about the role of the LMA in conjunction with IPPV. Equal figures (64%) of both consultants and senior registrars would not use an LMA for prolonged IPPV. Only 27% of the consultants considered there should be a maximum time limit beyond which they would not use an LMA, compared to 55% and 50% for the senior registrars and registrars.

The reported frequency of complications was not influenced by grade of operator; the most common complication was respiratory obstruction, occurring in approximately 6% of cases involving the LMA. It was noted that almost all anaesthetists removed the LMA in the operating theatre at the end of the surgical procedure rather than in the recovery room as advocated by Brain in the Intavent instruction manual [1].

The LMA has rapidly established itself in anaesthetic practice as highlighted by this survey, but it is interesting to note the differences in patterns of its use by different grades of anaesthetists.

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The laryngeal mask airway in recovery

We were interested to read Dr Davies' letter, 'A false compatibility' (*Anaesthesia* 1991; **46:** 991), especially in the context of the editorial in the same issue on supplementary oxygen [1]. We are sure that many anaesthetists share our view, that it was only a matter of time before a misconnection such as this was reported. Sadly, despite the availability of suitable T-piece systems for the delivery of supplementary oxygen to the laryngeal mask airway [2], this problem of connection to the high pressure oxygen supply is bound to recur. Brain has stated recently that 'Adequate anaesthesia during surgery and avoidance of disturbing the patient during recovery are certainly fundamental to smooth, uneventful use of the laryngeal mask' [3].

We suggest that misconnection and the problems associated with disturbance of the patient emerging from anaesthesia with the laryngeal mask in position could be completely avoided by removal of the laryngeal mask in the operating theatre by the anaesthetist whilst the patient is still anaesthetised. We consider this to be the safest approach and feel that delegation of the responsibility for care and removal of the laryngeal mask airway to anyone other than an anaesthetist should only be contemplated after careful consideration of the risks and benefits.

We have yet to find a good indication in the routine case for leaving the laryngeal mask airway in place during recovery.

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Defective feed mount

I would like to report a potentially serious hazard when using a feed mount attached to the common gas outlet of an anaesthetic machine. Figure 1 shows this set-up as used in our department to supply a variety of ventilators. On transferring the second patient of a cardiac operating list into the operating theatre, ventilation was controlled artificially using a Servo 900D ventilator which had been used without problems on the first patient of the day.

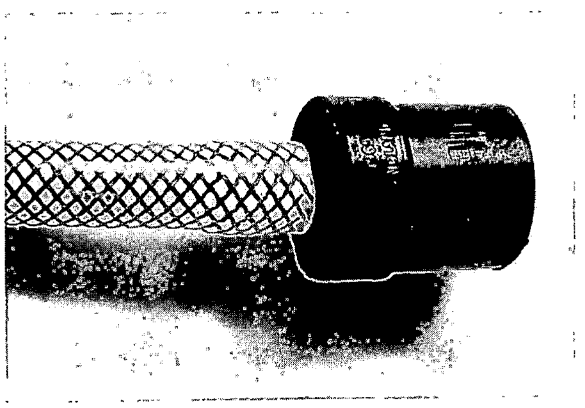

Fig. 1.

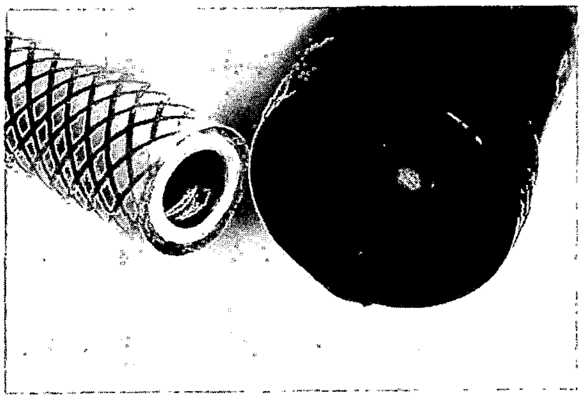

Fig. 2.

Despite adequate fresh gas flow from the Rotameter bank, the gas supply alarm of the ventilator constantly sounded. Checking the connection of the feed mount to the anaesthetic machine confirmed a tight fit. Further checks failed to pinpoint the problem. It was only on removing the feed mount from the machine to attach an alternative breathing system that the cause, shown in Figure 2, became evident. Despite a gas leak in excess of 3 l.min^{-1}, no audible loss could be heard and it is possible the leak would have gone unnoticed for a significant period if a ventilator without a gas supply alarm had been in use. The feed mount integrity needs to be confirmed before it is connected to the anaesthetic machine.

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Propofol for sedation in intensive care in a patient with an acute porphyric attack

A 24-year-old 55 kg female, previously not known to have porphyria, presented 10 days after the delivery of her second child when she developed epigastric pain and nausea. She then had multiple grand-mal and focal seizures for which she received a combination of phenytoin, clonazepam and carbamazepine. She was pyrexial and her white cell count was raised. Cerebral CT-scan and EEG were normal. A diagnosis of viral encephalitis was considered and she was commenced on acyclovir. Several days later she had a further episode of abdominal pain and it was noted that there were large amounts of porphobilinogen in her urine. Acute intermittent porphyria, precipitated by pregnancy, was diagnosed. All precipitating drugs were stopped and she received an increased glucose intake.

Over the next 8 days she developed a flaccid limb weakness involving upper and lower limbs. Her cough was poor and she experienced difficulty in swallowing. She was admitted to the neurosciences intensive care unit where it was decided to institute intermittent positive pressure ventilation. After pre-oxygenation she received alfentanil 1.5 mg, propofol 100 mg, suxamethonium 100 mg, her trachea was intubated and ventilation commenced. Sedation was continued with propofol at 150–200 mg.h^{-1} and alfentanil at 0·5 mg.kg^{-1}.min^{-1}.

She required ventilation for a total of 38 days, and received propofol 150–200 mg.h^{-1} for 32 days. After 15 days of propofol infusion her urinary porphyrin levels were markedly reduced (Table 1) and after 32 days of propofol her symptoms were almost resolved, apart from some residual weakness in her arms.

The porphyrias are a group of disorders characterised by defects in porphyrin metabolism, resulting in excessive production of porphyrins and their precursors, aminolaevulinic acid (ALA) and porphobilinogen (PBG). The symptoms of an acute attack are predominantly gastrointestinal, neurological and cardiovascular. Acute attacks may be precipitated or made worse by various anaesthetic drugs. The barbiturates, thiopentone and methohexitone, are the best known examples, but problems have been reported with etomidate, ketamine and diazepam [1,2]. Propofol has been reported not to be porphyrinogenic in the rat model [3] and there are several reports of its safe use as an intravenous induction agent [4,5]. Propofol for sedation in intensive care is well documented [6]; however, its long-term use in porphyria has not been reported previously. This case confirms that propofol appears to be a safe agent in patients with acute porphyrias, not only for the induction of anaesthesia, but also as infusions to provide sedation or anaesthesia.

Table 1. Urine porphyrin levels.

Urine concentration	Before propofol	15 days propofol	Normal range
ALA	714	190	0–40 μmol.l^{-1}
Porphobilinogen	845	296	0–16 μmol.l^{-1}
Uroporphyrin	> 9000	2390	> 40 nmol.l^{-1}
Coproporphyrin	790	275	< 70 nmol.l^{-1}

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Propofol and mono-amine oxidase inhibitors

The problem of anaesthesia for emergency surgery in patients receiving monoamine oxidase inhibitors (MAOI) for depressive illness invites varying opinions as to the safest drugs to administer peroperatively. Pethidine is known to be absolutely contraindicated [1] and morphine has been recommended as the drug of choice, although great potentiation of its depressive effects have been noted [2]. Similar potentiation of the effects of barbiturates have also been recorded [3]. Very little information is available about the safety of the shorter acting opioids or propofol in these circumstances, although the combination of alfentanil and propofol has been used uneventfully [4].

A 72-year-old woman presented for plating of a badly displaced fracture of her mandible. She had been receiving phenelzine for 15 years and was known to have a hiatus hernia, but was relatively asymptomatic. Ten years previously she had undergone an inguinal hernia repair and the patient clearly stated that she had continued phenelzine up to the time of surgery; unfortunately no anaesthetic record was available. Premedication comprised ranitidine 150 mg. Following pre-oxygenation and administration of propofol 80 mg, cricoid pressure was applied and anaesthesia continued by inhalation of enflurane in oxygen and nitrous oxide. Suxamethonium was avoided because the drug has a prolonged effect in MAOI therapy due to a decrease in cholinesterase concentration [1]. Nasal intubation was achieved easily and anaesthesia was maintained with spontaneous ventilation. The systolic blood pressure remained at 120–130 mmHg throughout the procedure with a steady pulse rate. Analgesia was provided by diclofenac 75 mg intramuscularly and surgical infiltration of 0.25% plain bupivacaine. The patient awoke rapidly and was pain free. Further doses of diclofenac were provided for postoperative analgesia.

This report supports the view that propofol is a suitable agent for use in patients receiving concurrent MAOI therapy.

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Failed tracheal intubation

I am concerned by yet another report of deaths from failed tracheal intubation (*Anaesthesia* 1991; **46:** 962–966). If patients are to die at all, it should be because of failed cricothyroidotomy and not failed orotracheal intubation. I would be most interested to know how many of the seven cases of primary failure to intubate the trachea (as opposed to unrecognised oesophageal intubation) had a cricothyroidotomy, at what stage of hypoxia it was carried out, if at all, what exactly was the cause of death (i.e. failure to ventilate, aspiration, etc). It could be that some of these patients might have been salvaged by successful, early cricothyroidotomy?

I suspect that, like the failure to consider oesophageal intubation, professional intransigence results in a refusal to admit 'failed' orotracheal intubation, particularly by senior anaesthetists, and that both lack of experience and fear of complications makes us resistant to the life-saving surgical approach. Confidence can be acquired by performing and teaching surgical and needle cricothyroidotomy on cadavers. I have recently trained three senior house officers, all of whom inserted a size 7 mm cuffed tube into the trachea via the cricothyroid membrane in under 25 s; they had no previous experience and only a scalpel and a pair of forceps. This formal surgical approach is recommended in preference to minitracheotomy or a Seldinger technique, because it is quicker. Needle cricothyroidotomy is not much faster, requires unfamiliar high pressure ventilation via often unreliable Heath-Robinson attachments and is associated with a substantial risk of barotrauma. I strongly urge all those anaesthetists who are at high risk of encountering difficult airways, particularly obstetric anaesthetists, to visit their local anatomy or pathology department, if they do not have prior experience of cricothyroidotomy.

Correspondents have recently discussed alternative methods of intubation, such as the laryngeal mask [1]. I agree that these techniques should be practised, but consider that they are only applicable before hypoxia has supervened, in the patient who can still breathe spontaneously or be adequately ventilated by facemask, but cannot be intubated. Even then, the necessary release of cricoid pressure and continued risk of aspiration [2] may justify the surgical introduction of a cuffed tube. In the nightmare scenario of failure to both intubate the trachea and ventilate the lungs effectively, with an $S\mathrm{po}_2$ rapidly falling below 90%, one must have the courage to perform cricothyroidotomy immediately.

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Basic life support performance

In most hospitals the responsibility for cardiopulmonary resuscitation (CPR), in which anaesthetists play a major role, usually rests with doctors in training. The importance of basic life support (BLS) is well established and intrahospital cardiac arrests are more likely to survive if CPR is properly administered. Unfortunately, most hospitals and doctors assume that they are competent in CPR and so do not attend BLS/CPR training courses.

We conducted a study on the performance of all junior anaesthetists in our anaesthetic department (14 SHO/Registrars), all of whom considered themselves competent to manage a cardiac arrest, using a Resussi-Anne Laerdal manniquin. The results were disappointing. None could fulfil the rigorous criteria set by the American Heart Association for successful BLS/CPR. Only five were able to open/maintain an open airway without an oropharyngeal airway or tracheal tube, and of those only four could then ventilate the manniquin's lungs efficiently. All candidates selected wrong site(s) for cardiac compression with insufficient depth of compression; six also compressed very slowly (less than 60 min^{-1}).

Why did anaesthetists fail to maintain an open airway? Is it that we are so accustomed to using naso/oropharyngeal airways and tracheal tubes that we are helpless without them; but even then these anaesthetists failed to ventilate the lungs efficiently. Our results did not differ from previous studies on surgical and medical staff, it merely added anaesthetists to that list. Again our recommendations are the same, anaesthetists should be properly trained in the art of BLS/CPR and as the experience does fade with time, this may have to be repeated yearly.

The worthwhile part of the study was that all candidates who spent almost 30–45 min to reperform the test after knowing their pitfalls, had a pass score.

St James Hospital,
Dublin 8

M.A.Y. Elias

A malformed guidewire

I anaesthetisted a neonate for closed heart surgery. The child had a short 22 SWG catheter in the right posterior tibial artery, which had kinked and no longer gave a reliable reading of arterial blood pressure. A 22 SWG Secalon Hydrocath (Viggo) was chosen to replace the arterial catheter. The guidewire was passed through the short catheter into the lumen of the artery and the catheter was withdrawn, but would not pass over the outer end of the guidewire. Close inspection revealed a deformity which had increased the diameter of the guidewire, as shown in the figure. The short catheter was passed back into the artery and the guidewire was withdrawn. A new Hydrocath kit was used to replace the catheter.

Had the Hydrocath kit been used to gain access to the artery, both the introducer needle and the guidewire would have had to have been withdrawn, and the arterial access would have been lost. I would recommend that colleagues inspect a guidewire before using it, and check that the intended catheter passes over the whole length of the wire.

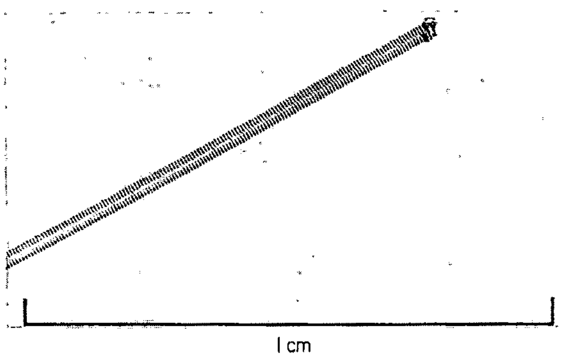

Fig. 1

Bristol Royal Hospital for Sick Children,
Bristol BS2 8HW

W.R. Harvey

A reply

Our examination of the guidewire in question revealed that whilst the end union of the outer coils to the inner core remained securely attached, adjacent outer coils had overridden the end termination creating an oversize condition. The resultant effect was a restricted passage over the guidewire. We have no evidence to suggest whether the fault originated with the guidewire manufacturer or subsequently as a result of handling and use.

We support the writer's recommendation that guidewires be examined prior to use and especially after removal, whether restriction to free passage has been encountered or not. Also, as in this case where different manufacturers' products are used or being interchanged and it is not possible to establish compatibility physically prior to use, reference should be made to actual wire and lumen dimensions stated on product packaging.

Viggo-Spectramed,
Swindon,
Wiltshire SN3 5HO

A.J. Percival

'Slipped' trachea during laryngo-oesophagectomy

A 54-year-old man, scheduled for laryngo-oesphegectomy, was anaesthetised via a tracheal tube initially, which was subsequently changed to a tracheostomy tube. Following a sharp and blunt dissection, the larynx was separated and a total laryngectomy performed, followed by a gastric pull-up procedure. During the final refashioning of the tracheostomy the tracheal stoma slipped back from the tracheostomy tube, with loss of ventilation and rapid arterial desaturation. The surgeon was able to hold the posterior wall of the slipped tracheal stoma, but did not attempt to pull it for fear of tearing it again and completely losing the stoma into the wound. Direct attempts to intubate the stoma failed as it was very mobile, so a bougie was passed into the stoma and a 7 mm armoured tube threaded over it. This passed initially into the right main bronchus, but oxygenation improved and the tube was then pulled back into the trachea, allowing ventilation of both lungs. Manubrium resection to mobilise the trachea was then done and a new stoma–tracheostomy made. The rest of the operation and the recovery were uneventful.

In this patient, the retracted trachea was so mobile due to extensive manipulation and dissection of the cervical–mediastinal structures, that direct attempts to intubate the stoma using a Portex and a rubber tube failed. Another alternative was to pass a catheter and insufflate the trachea with 100% oxygen, but this does not afford protection from aspiration; an increase in $Pa\text{O}_2$ is inevitable. The use of a jet ventilator was considered, but it was not possible to set this up in the available time.

The most likely cause of the problem was that a tear had occurred in the posterior wall of the trachea, which extended anteriorly leading to complete transection. This might have resulted from tracheal weakness caused by direct involvement by the tumour, or lack of support following extensive dissection and resection around the trachea and the gastric pull-up procedure.

St. James Hospital, Dublin 8 M.A.Y. Elias

Exaggerated epidural blockade?

We read with interest the case report by Popat, Jadad and Glynn (*Anaesthesia* 1991; ***46:*** 859–61), but disagree with some of their conclusions. They describe a case of exaggerated epidural blockade in a 75-year-old patient with low back pain. An initial dose of 3 ml of plain bupivicaine was injected at the L_1–L_2 interspace without effect and was followed by 10 ml of 0.5% bupivicaine (i.e. a total of 0.8 ml or 4 mg per segment if the initial dose is included), which resulted in a block extending from C_4 to L_1. Bromage [1] recommends a dose of 4 mg per segment in a patient of this age, but in this case the distribution was unusual. From this report, however, the reasons for the spread of bupivicaine achieved remain unclear. The authors inserted an epidural catheter 24 h later at the T_{11}–T_{12} interspace and injected 1.5 ml of radiopaque dye (Niopam). The caudal spread of dye did not extend below the level of L_1 and the authors concluded that this was a case of exaggerated epidural blockage with a possible obstruction at L_1.

This small volume of radiopaque dye was said to give a spread similar to that of the epidural reported earlier. However, this radiographic examination was not performed through the same catheter, but one re-inserted two interspaces higher than the previous epidural. Previous studies have failed to find a correlation between the spread of contrast in the epidural space and sensory blockade unless larger volumes of dye are used [2,3]. The block at L_1 in this case may have been due to mechanical obstruction, but could also have arisen as a result of the curve of the thoraco-lumbar spine which would encourage upward spread of this small volume of dye. The injection of a larger volume of dye at the same lumbar interspace as the previous epidural injection may have clarified the situation. As a result of these radiographic findings, the authors were confident that the epidural catheter was not placed in the subdural space. Their statement that 'contrast media injected into the subdural space does not move freely and causes a sausage shaped shadow as a result of the material travelling up and down the thecal tube' is, however, unsubstantiated by reference in the literature. Indeed, spread of contrast in the subdural space is well documented.

Following both intentional [4] and unintentional placement [5–9] of catheters in the subdural space, contrast has been shown to be sheet-like and to move freely, lie predominantly dorsally and spread mainly cephalad. Subdural migration of epidural catheters has also been described [10]. The block in this reported case could, therefore, have arisen from a subdural injection of bupivicaine but it is impossible to be certain because dye studies were not performed through the original catheter.

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A reply

We welcome the opportunity to reply to Drs Magides and Birks letter. We did attempt radiographic studies with the original catheter, but as stated in our report, this was displaced in the subcutaneous tissue and had to be removed. A catheter was resited at the T_{11}–T_{12} interspace because of failure to identify the L_1–L_2 interspace.

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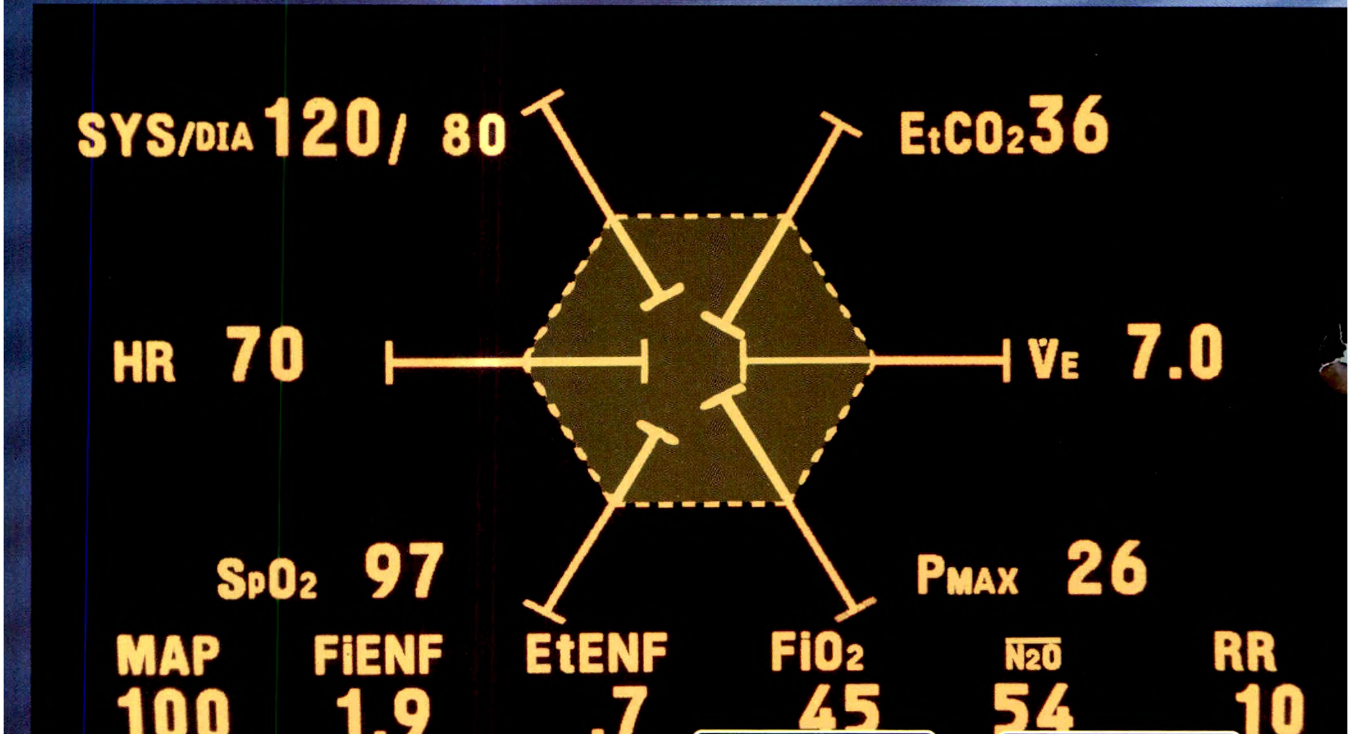

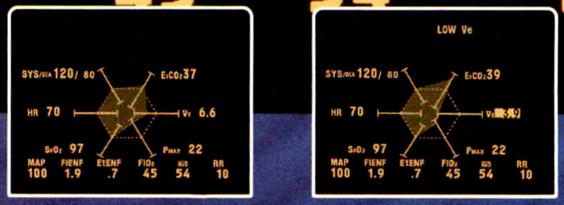

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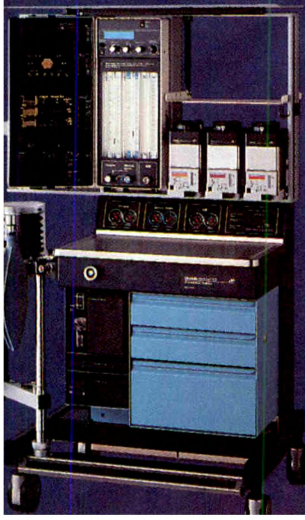

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We agree with the authors that the correlation between spread of contrast and sensory blockade is poor. We did not use the radiographic findings in our case to demonstrate the exact segment-to-segment relationship of the contrast and local anaesthetic, but to demonstrate the mechanical block at L$_1$ and cephalad spread of dye. The radiographs were taken immediately after injection of contrast (to limit reabsorption), with the patient in the lateral position, thus obviating the lumbosacral curve. We did not feel larger volumes of contrast would clarify matters further. Indeed, large volumes of low concentration dye can result in the contrast not being visible on X-rays [1].

Clinical signs of a subdural block were not present in our patient, hence we concluded that the first catheter was unlikely to be subdural. Lastly, our statement that 'when contrast media are injected into catheters in the subdural space, they do not move freely and cause a sausage-shaped shadow as a result of the material travelling up and down the thecal tube' is stated in the classical text, *Epidural analgesia* by Bromage [2]. However, on reviewing the references [3–8], it is clear they do not support Bromage's description which is not referenced.

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M.T. Popat
A.R. Jadad
C.J. Glynn

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Missing O-ring causes unrecognised large gas leak

We wish to report an instance where a large unrecognised gas leak led to underventilation of a patient.

An edentulous 80-year-old woman (ASA grade 1) was anaesthetised for endoscopic resection of an anal polyp. She was premedicated with metoclopramide 7.5 mg and glycopyrronium 0.2 mg intramuscularly. General anaesthesia was induced with propofol 70 mg and maintained with halothane in nitrous oxide : oxygen (50 : 50) via a size 3 MIE facepiece and a disposable Magill breathing attachment, with spontaneous ventilation.

Following induction of anaesthesia, it was noticed that the reservoir bag was failing to inflate normally during expiration. This was thought to be due to a poor seal around the face piece with consequent gas leak. The fresh gas flow was increased from 12 to 16 l.min^{-1}, but the patient became increasingly tachypnoeic and tachycardic, with a heart rate of 112 beats.min^{-1}. A LMA size 3 was inserted to provide an airtight seal, following which the reservoir bag still failed to inflate fully. The patient was immediately transferred from the anaesthetic room to the operating theatre and connected to the anaesthetic machine, whereupon her respiratory rate and heart rate rapidly fell to normal. Her $S\text{po}_2$ on transfer was 99%. The remainder of the anaesthetic was uneventful and she made a normal recovery.

Subsequent inspection of the original anaesthetic machine revealed that gas flow was normal with the halothane vaporizer turned off or set at 0%, but with the vaporizer switched on, irrespective of the setting, gas flow at the common gas outlet fell to between zero and 1 l.min^{-1} depending on the flow through the Rotameter block. A quiet hiss was audible at close range from the vaporizer. Removing the vaporizer revealed that one of the two rubber O-rings was missing (Fig. 1). The vaporizer had been used in a preceding case on the same operating list with no apparent abnormality. The vaporizers in the operating theatre and in the anaesthetic room had been exchanged the previous day, and presumably at this stage the O-ring had inadvertently become displaced.

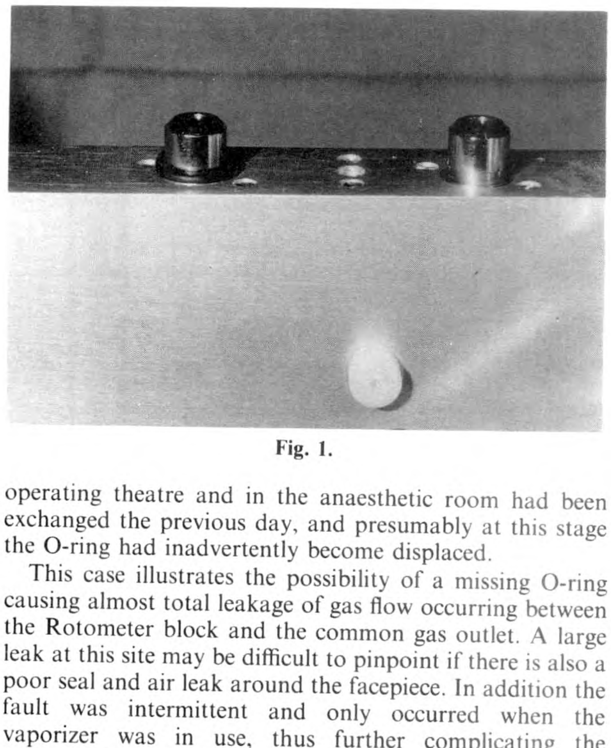

Fig. 1.

This case illustrates the possibility of a missing O-ring causing almost total leakage of gas flow occurring between the Rotometer block and the common gas outlet. A large leak at this site may be difficult to pinpoint if there is also a poor seal and air leak around the facepiece. In addition the fault was intermittent and only occurred when the vaporizer was in use, thus further complicating the identification of a leak. The importance is emphasised of performing the occluson tests for leakage with the vaporizer dials in both 'on' and 'off' positions, as recommended by the Association of Anaesthetists.

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P.D. Berry
D.G. Ross

Measurement of VAS pain scores with a 'magic screen'

The recent emphasis on improving pain relief after surgery has highlighted the need for a simple method of scoring pain. The 10 cm visual analogue scale has been shown to be sensitive and reliable in this respect. We have adapted a child's toy to produce a re-usable method of recording our patients' VAS. This has improved our ability to audit pain

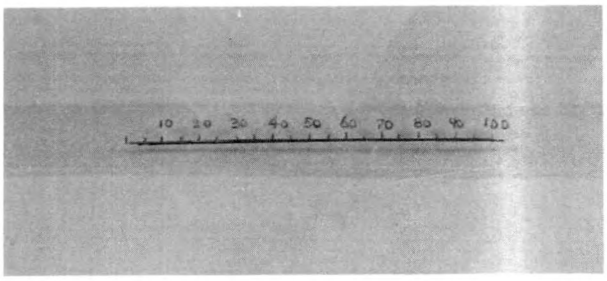

Fig. 1.

levels following thoracic surgery. An indelible 10 cm line, drawn on the back of a transparent acetate sheet is stapled to the front of a 'magic screen'. A simple plastic ruler is attached which allows rapid measurement of the patient's VAS score (Fig. 1.). The device has the advantage of complete erasure of the previous mark while minimising waste paper. The prototype, at less than 50p, has proved to be robust, helping to monitor over 200 patients following thoracotomy in a 6-month period.

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H. SPENS
G.C. PUGH

The potential hazards of using iodine as an antiseptic solution

I read with interest the letter by Dr O'Kelly and Professor Parsons (*Anaesthesia* 1991; **46:** 1000–1). This concerned the theoretical consequences of a chemical reaction between aluminium foil containers and liquid iodine used as an antiseptic. The formulation was not detailed and our Pharmacy Department was only able to give information on a similar antiseptic. This contained 25 g iodine and 25 g potassium iodide dissolved in 25 ml water and then made up to a 1000 ml with absolute ethanol.

Aluminium is an extremely interesting element and as soon as clean aluminium is exposed to oxygen a dense, tough and transparent layer of Al_2O_3 forms. This prevents further oxidizing of this highly reactive element. The oxide layer can be destroyed, but the large negative value of -1675 kJ.mol.$^{-1}$ for the enthalpy of formation of Al_2O_3 indicates the stability of this compound. If you chemically remove this protective layer from the surface of pure aluminium and add a reactive compound, I would agree with the authors that a severe reaction, of the type they describe, may occur.

If powdered aluminium is heated in the presence of I_2 and ether, there will certainly be an explosion risk. I am sure we are not dealing with these situations in hospital practice. We must avoid extrapolating the effect seen with powdered aluminium, and its concomitant large surface area to mass ratio, to that seen in basically a sheet metal. I doubt if we should be changing our practice, by adopting any of the authors' recommendations, unless it is clearly shown that hydroiodic acid is indeed produced.

I would be interested to know whether recyclable aluminium containers are commonly used, in any case, for holding liquid iodine antiseptic.

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D. WATSON

Anaphylactoid reaction to ranitidine in an obstetric patient

Ranitidine is the preferred H_2 receptor antagonist used for acid aspiration prophylaxis during labour and for Caesarean section in the UK [1]. It is more potent than cimetidine and appears to have fewer side effects. We would like to report an anaphylactoid reaction that occurred when ranitidine was given orally to a patient the evening before a planned elective Caesarean section.

A 31-year-old, 76 kg, Somalian patient was scheduled for an elective Caesarean section for cephalopelvic disproportion. Twenty months previously she had undergone an uncomplicated Caesarean section for fetal distress under general anaesthesia. During that labour she was given ranitidine 150 mg orally and also 50 mg intravenously prior to induction of anaesthesia. She was taking thyroxine 0.2 mg daily which had been started in 1984 following a thyroidectomy. There was no history of drug allergy and pregnancy had been uncomplicated.

On the evening before surgery the patient was given 150 mg ranitidine orally. Thirty minutes later she complained of dyspnoea, chest and loin pain and pruritis. On examination she had swelling of her face and tongue. Her pulse rate was 120 beat.min^{-1} with a normal arterial blood pressure and her chest was clear on auscultation. She was immediately given oxygen via a facemask and 10 mg chlorpheniramine intravenously. The fetal heart rate was 145 beat.min^{-1} and the cardiotocograph (CTG) was satisfactory. Following the injection of chlorpheniramine the symptoms resolved. Later, she started to complain of intermittent abdominal pains consistent with the onset of labour. Pethidine 50 mg and metoclopramide 10 mg were given intramuscularly. Vaginal examination showed a soft cervix 1–2 cm dilated with intact membranes. The patient then underwent an elective Caesarean section using spinal anaesthesia, 7 h after the anaphylactoid reaction to ranitidine. Following circulatory preload with 1 litre compound sodium lactate solution hyperbaric bupivacaine 2.5 ml was injected intrathecally using a 24 gauge Sprotte needle at the L_{3-4} interspace. A live female infant (Apgar scores 8 at 1 min and 9 at 5 min) was delivered 10 min later. The mother was given two, 3 mg incremental doses of ephedrine intravenously when the systolic pressure fell to 65/40 mmHg, 20 min after the injection of bupivacaine.

To our knowledge there has only been one previous report of an anaphylactoid reaction to ranitidine in an obstetric patient [2]. Such reactions can occur even without previous exposure to the drug and usually consist of dyspnoea, stridor, urticaria and facial and lingual oedema. The symptoms respond to chlorpheniramine and hydrocortisone, but it is important to recognise and treat the problem early, in order to minimise maternal and fetal distress. If emergency Caesarean section is required then spinal anaesthesia is an appropriate technique providing that the fluid lost from the circulation has been replaced and the patient is cardiovascularly stable. General anaesthesia may be associated with difficulty in tracheal intubation if facial and lingual oedema are still present. The anaphylactoid reaction in our patient was probably responsible for the onset of labour, but fortunately there was little evidence of fetal distress and the Caesarean section was carried out a few hours later when the facial oedema had resolved. Omeprazole [3] might be a suitable alternative to ranitidine if this patient required another Caesarean section in the future. We have reported the case to the Committee on Safety of Medicines and the drug manufacturers. It would be interesting to know of any other similar cases.

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R. Madan
P.B. Hewitt

References

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[2] Greers IA, Fellows K. Anaphylactoid reaction to ranitidine in labour. *British Journal of Clinical Practice* 1990; **44:** 78.

[3] Gin T, Ewart MC, Yau G, Oh TE. Effect of oral omeprazole on intragastric pH and volume in women undergoing elective Caesarean section. *British Journal of Anaesthesia* 1990; **65:** 616–9.

The upside down facemask again

We read with interest the letter from Drs Northwood and Wade (*Anaesthesia* 1991; **46:** 319) on the use of an upside down Rendell–Baker Soucek mask in patients with a permanent tracheostomy, and applied a similar technique to a different situation.

We had been having difficulty in obtaining an airtight seal with a facemask during induction of anaesthesia for patients undergoing transnasal surgery of the pituitary. As many of these patients are acromegalic and the largest mask in our department is a size 5 the problem is fairly obvious! We therefore decided to turn the mask upside down such that the nasal portion of the mask lay over the jaw, whilst the ODA pinched the patient's nose. This, together with the use of a suitable oral airway, proved very successful in three patients enabling us to ventilate adequately the lungs by hand. Indeed in two of these patients the normal 'chin' portion of the mask actually occluded the nares thus obviating the need to pinch the nostrils.

This technique has also proved to be very useful at the end of this and other types of nasal surgery when the presence of nasal packing can make the use of a facemask difficult.

Royal Hallamshire Hospital,
Glossop Road,
Sheffield S10 2JF

W.C. Edmondson
A. Rushton

Another use for paediatric masks

Pre-oxygenation or induction of inhalation anaesthesia through a paediatric mask on the tracheostomy, as described by Drs Northwood and Wade (*Anaesthesia* 1991; **46:** 319), would seem a useful suggestion with the advantage, particularly for infants and children, of not further reducing the available lumen as do the alternatives of wedging a connection or tube into the tracheostomy tube. On occasion, paediatric masks have proven useful to cover the nose only.

A 12-year-old, 36 kg male was first seen with a hard, walnut-sized swelling of the right anterior mandible, when 7 years old. Four years elapsed before his next visit to the hospital, little changed, when a biopsy suggested fibrous dysplasia. A year later he came again, complaining of bleeding from an intra-oral swelling, and his haemoglobin was found to be 5 g.dl^{-1}. He was much discomforted by his appearance (Figs 1 and 2) and kept face and neck wrapped in a towel exposing only eyes upwards. A surgical biopsy under general anaesthesia caused profuse bleeding and transfusion of 2 l of plasmalyte and two units of packed red cells. During the wait for the histology report his haemoglobin fell to 3.8 g.dl^{-1} necessitating more transfusions. These events made the parents extremely reluctant to consent to more surgery for fear of losing their son.

At both surgical biopsy and mandible resection inhalation anaesthesia was induced through a paediatric mask over the nose. Lignocaine 4% was applied to the glottis with a Macintosh spray and a 6.5 mm cuffed nasotracheal tube inserted blindly. Lack of access prevented placement of a pharyngeal pack. The plan was to move to the X ray department for angiography and selective vessel embolisation, but an assistant supporting the tumour relaxed at an injudicious time and a section of its attachment tore, precipitating brisk bleeding,

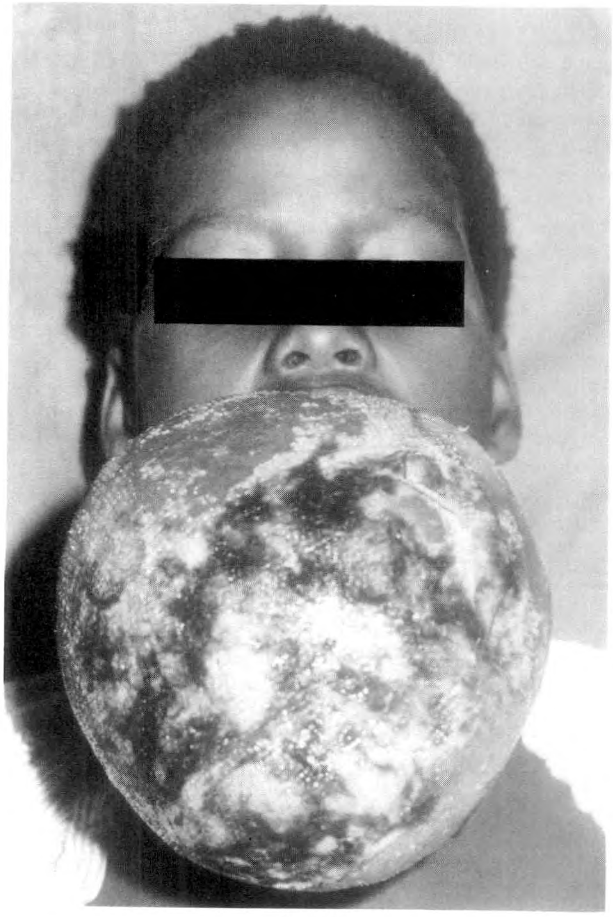
[redacted]

Fig. 1.

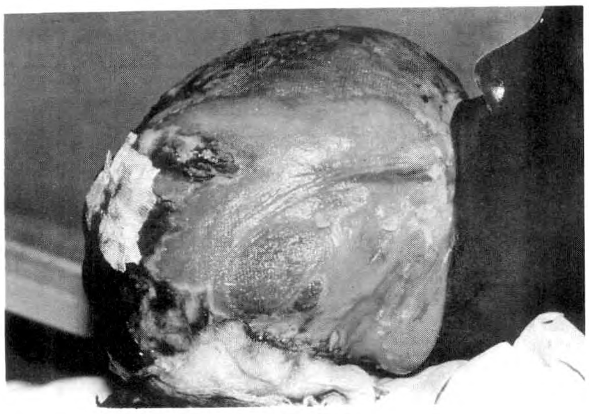

Fig. 2.

fortunately controlled by local pressure, and thence the surgery. In a 3 h procedure the mandible was resected through the premolar regions, Kirchner wires placed, and the mouth floor and buccal mucosa sutured. Anaesthesia included halothane, alcuronium, droperidol, fentanyl, trimetaphan and labetalol. The tracheal tube was removed after 72 h and the patient returned from ICU to the general ward.

In the second postoperative week, salbutamol nebulisation was prescribed for slight wheezing in the chest and the patient soon after discharged with a supply of salbutamol. Only 2 days later at outpatient follow-up, grunting and stridor prompted admission to the ENT ward. A 1 cm length of tracheal stenosis 1.5 cm below the vocal cords was seen at endoscopy and a supraclavicular lymph node biopsy proved full of caseous material. The patient's trachea was kept intubated for 5 days and antituberculosis medication commenced. Chest X ray showed a mass of mediastinal and lower cervical nodes compressing the trachea. Tracheal biopsy histology reported nonspecific mixed inflammation. After four more general anaesthetics to examine the airways, remove a granuloma and dilate the trachea the patient was once more discharged.

The resected specimen measured 20 cm × 17 cm × 17 cm, weighed 3.52 kg and had the histology of ossifying fibroma (probably juvenile or aggressive type).

King Edward VIII Hospital
Durban,
South Africa

R. Williamson

'On/off' switches on anaesthetic machines

Over recent years it has become customary for newly purchased anaesthetic machines to have incorporated a pneumatic switch. This interrupts the flow of all anaesthetic gases apart from the emergency oxygen flush when in the 'off' position. In our view this merely provides another possible source for failure of the gas supply to the patient if the switch malfunctions [1]. We wish to present a case where this in fact occurred, confirming our suspicions.

An anaesthetic machine (MIE Cavendish 460) was fully checked by the anaesthetist pre-operatively. Testing included a single hose disconnection test, after the completion of which gas was seen to flow through both the nitrous oxide and oxygen flowmeters. Pipeline and cylinder pressures were checked, as was the security of all connections. The indicator adjacent to the on/off switch was green, with the switch in the up, 'on', position. A few minutes later, following the transfer of an anaesthetised patient from the anaesthetic room into the operating theatre, the on/off indicator, which was in the on position, still showed green, but no gas was delivered from the machine other than from the emergency oxygen flush; the nitrous oxide and oxygen flowmeters were open. The patient was returned to the anaesthetic room and the anaesthetic machine was exchanged for another, older, type which did not have a pneumatic on/off switch. This machine worked satisfactorily, allowing anaesthesia and surgery to proceed uneventfully. Subsequent examination of the anaesthetic machine revealed that the switch could be placed in a neutral position, interrupting the gas supply, but with the indicator remaining in the green, 'on' position.

The pneumatic switch, although robust, clearly has the potential to malfunction after a modest period of use (1 year). Although no overt abnormality was detected when the switch was removed from the machine it was examined and replaced by the MIE service engineer. We are of the opinion that the incorporation of such switches into anaesthetic machines does not enhance patient safety.

Royal Hospital for Sick Children,
Glasgow G3 8SJ

S.R. Haynes
C.J. Best

Reference

[1] Best CJ. Monitoring for anaesthesia. *Lancet* 1987; **ii:** 1033–4.

A reply

Thank you for the opportunity to reply to the letter from Drs Haynes and Best.

MIE machines, like many other modern anaesthetic machines, are, as Drs Best and Haynes mention, fitted with 'mains' on/off switches primarily to turn off the basal flow of oxygen.

The switch fitted to the Cavendish 460 in question is a standard component and is purely pneumatic. The action of the switch is designed so that it is extremely difficult to set in a neutral position. With the tests we have carried out, on the actual switch removed from the machine, it has proven impossible to set the switch in a neutral position and at the same time prevent gas flow. Also, the flow indicator adjacent to the switch on our machines can only change from red to green if gas actually flows. We are therefore at a loss as to how this incident has happened.

Our engineer, who was called to the hospital and replaced the switch, could not simulate the fault described even after an hour of switching the machine on and off repeatedly. We have had no other reports of this nature in the 6 years we have been fitting these switches, which hopefully shows that the incorporation of such a switch does not compromise patient safety.

Director of Technical Sales,
M & IE,
Sowton Industrial Estates, Exeter EX2 7NA

T. Longman

Splitting tubes

We would like to report another possible cause of patient disconnection from the anaesthetic breathing system, this time associated with a possible manufacturing fault in equipment.

While checking the connector inserted into the end of a Kendal Curity tracheal tube it was noticed that the tube was split at the end along the radiologically opaque line, causing the fitting to be loose. A second tube was prepared and although the fitting was now tight and the tube had not split, it was noted that the opaque line was stretching (Fig. 1). We feel that this weakness in the tracheal tube is a manufacturing design or production fault and needs to be specifically looked for when using these particular tubes.

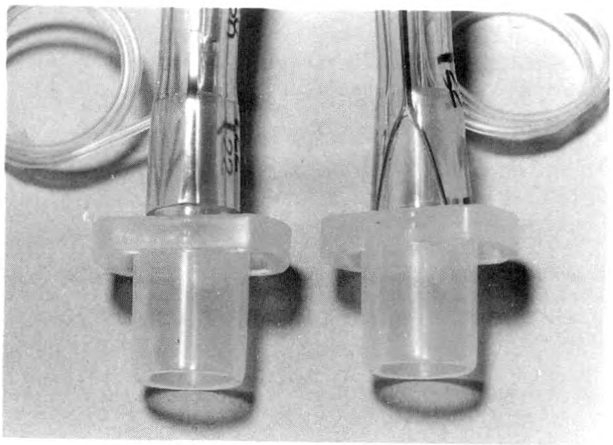

Fig. 1.

Peterborough District Hospital, M.B. Smith
Peterborough PE3 6DE J.D. Watts

A reply

Thank you for the opportunity to reply.

Drs Smith and Watts' communication related to a problem encountered with a small number of our 8.00 mm Curity cuffed tracheal tubes which occurred in October 1991. Immediate corrective action was taken at that time to improve product specifications and manufacturing controls, supported by the rapid implementation of a replacement programme for all 8.00 mm Curity tracheal tubes out in the market.

In view of the time elapsed since the original complaints were dealt with, and the publication of Drs Smith and Watts' letter, we are natually concerned that this is not seen as a recurrence of the original problem.

Director, Regulatory Affairs/Europe, J. Lloyd Davies
The Kendall Company (UK) Ltd,
Basingstoke,
Hampshire RG24 0WG

Local anaesthesia for reduction of neonatal inguinal hernia

Inguinal herniae are the most common reason for surgery in the neonatal period. An irreducible hernia in this age group poses a problem relating to analgesia. I wish to report a case using a technique not previously described.

A 2-week-old male twin neonate was admitted to a general paediatric ward with a short history of right-sided scrotal swelling. Although he had been feeding well, he had vomited on one occasion. On examination, there was an inguinal hernia containing loops of bowel extending into the scrotum. This was irreducible and appeared to be tender with mild erythema of the scrotal skin. The child was distressed and there was a palpable impulse with each cry. It was felt that without muscle relaxation or analgesia, the hernia would remain unreduced, and my help was sought. A 0.125% solution of plain bupivicaine was prepared and 2.5 ml (3.125 mg) was infiltrated around the neck of the hernia using a 25 gauge needle. Within 5 min of this procedure, it became possible to reduce the hernia to less than half its original size using gentle manual pressure. This could be done without causing distress. Twelve hours later, the hernia was entirely reduced, and the child was discharged home to await elective surgery.

The susceptibility to respiratory depression by opioids makes their administration to a neonate a problem. In a district general hospital, it may be difficult to provide adequate monitoring or ventilatory support for a child of this age. The use of regional techniques provides an alternative and safer method for analgesia, so long as certain precautions are observed. Toxic effects from local anaesthetic agents are more likely in the neonate, because drug distribution differs from that of the older patient with alterations in body water and fewer protein binding sites [1]. Lower levels of alpha$_1$ acid glycoprotein result in increased free fraction of bupivicaine [2]. For these reasons it is important to restrict the maximum dose of local anaesthetic, especially if used in a vascular area. In this case, bupivacaine was chosen for its duration of action, but the dose given was limited to 1 mg.kg^{-1}. Perhaps the adult dose of 2 mg.kg^{-1} is too high?

University Department of Anaesthesia, O.A. Williams
Sheffield S10 2RX

References

[1] Besunder JB, Reed MD, Blumer JL. Principles of drug biodisposition in the neonate. A critical evaluation of the pharmacokinetic-pharmacodynamic interface. *Clinical Pharmacokinetics* 1988; **14:** 189–216.

[2] Mazoit JX, Denson DD, Samii K. Pharmacokinetics of bupivacaine following caudal anaesthesia in infants. *Anesthesiology* 1988; **68:** 387–91.

Doxapram after general anaesthesia

We were interested to read Drs Sarma and Fry's paper (*Anaesthesia* 1991; **46:** 460–1) concerning the role of doxapram in the treatment of postoperative shivering. They state that 60–100 mg of doxapram were administered to those patients who failed to stop shivering within 5 min of their initial treatment. The data they present do not, however, identify the numbers of patients who required this additional treatment. Consequently we cannot identify the number of patients in the doxapram treatment group, who took longer than 1 min to stop shivering, who also had this extra dose of doxapram. More importantly, we also cannot tell what proportion of the five patients in the placebo group who took longer than 1 min to stop shivering, went on to recieve doxapram prior to the cessation of shivering.

Without further clarification we feel that the efficacy of doxapram in the treatment of postoperative shivering cannot exactly be determined.

Northern General Hospital,
Herries Road
Sheffield

I.J. BROOME
G.H. MILLS

A reply

Thank you for giving me an opportunity to reply to Drs Broome and Mills. There appears to be some confusion regarding the data presented in Table 2 of the article. We should have specified that in Table 2, line 4, the seven patients in the doxapram group and the five in the placebo group who took more than 1 min to stop shivering all did so within 5 min of initial treatment and hence did not require additional doxapram. As the results after injecting the initial drug were significant, we did not feel it was necessary to give details of patients who required additional doxapram and time taken to stop shivering after a known drug was given.

Additional doxapram was given to 29 patients, of which 22 were from the placebo group; 16 of the placebo group patients stopped shivering within 1 min, one took nearly 15 min and five stopped shivering within 4 min of administering additional doxapram. Seven patients in the doxapram group required additional doxapram. Of these one stopped shivering within a min, five responded in 5 to 10 min and one took longer than 10 min.

I hope this clarifies any doubts these authors may have regarding efficacy of doxapram in the treatment of postoperative shivering.

North Tees General Hospital,
Stockton-on-Tees,
Cleveland TS19 8PE

V. SARMA

Insertion of interpleural catheters

We congratulate Drs Marsh and McDonald on their modified technique for insertion of interpleural catheters (*Anaesthesia* 1991; **46:** 889). However, we would like to point out that this method has been described previously [1]!

Vanderbilt University Hospital
Nashville,
Tennessee 37232-2125, USA

E.M. LEE

Herzliya Medical Centre,
Haifa, Israel

B. BEN-DAVID

Reference

[1] BEN-DAVID B, LEE E. The falling column: a new technique for interpleural catheter placement. *Anesthesia and Analgesia* 1990; **71:** 212.

Anaesthesia, 1992, Volume 47, pages 365–366

Obituaries

Kent, B.S., MB, BS, FFARCS. Formerly Consultant Anaesthetist at Eastbourne Hospital. Qualified from London University (Middlesex Hospital) in 1937.

Robertshaw, F.L., MB, ChB, FFARCS. Formerly Consultant Anaesthetist, Trafford Health Authority. Qualified from St Andrews University in 1944.

Dundee, J.W., MD, PhD, FRCP, FFARCS. Formerly Professor of Anaesthesia, Queen's University Belfast. Qualified from Queen's University in 1946.

Manley, R.E.W., MB, BS, DA. Formerly managing director Medical Developments Ltd. Qualified from University of London (Westminster) in 1957.

Davies, R.M., MRCS, LRCP, FFARCS. Formerly Consultant Anaesthetist, Queen Victoria Hospital, East Grinstead. Qualified from Westminster Hospital in 1939.

Williams, T.M., LRCP, MRCP, FFARCS. Formerly Consultant Anaesthetist, Morriston Hospital, Swansea. Qualified from St. Bartholomew's Hospital in 1942.

International congress calendar

1992

1–3 April. Bristol. *Junior Anaesthetists' Group Linkman Conference and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

23–25 April. Atlanta, Georgia, USA. *2nd International Symposium on Memory and Awareness in Anesthesia.*
Information: Mrs Kathleen A. Maitland, Department of Anesthesiology, Emory University at Crawford Long Hospital, 25 Prescott Street, 5405 Glenn, Atlanta GA 30308, USA.

2–6 May. Boston. *Society of Cardiovascular Anesthetists.*
Information: P.O. Box 11086, Richmond, Virginia, 23230-1086. USA.

19–22 May. Lyon, France. *XVth International Symposium on Clinical Hyperthermia.*
Information: XVth ICHS Meeting, Dr F.N. Gilly, Dr A.C. Sayag, Dr P.Y. Carry, Secretariat de Chirurgie Generale, Centre Hospitalier Lyon-Sud, 69310 Pierre Benite, France.

21–24 May. Montreal, Canada. *4th International Neuromuscular Meeting.*
Information: Clair Diano, Post-Graduate Board, Royal Victoria Hospital, 687 ouest, Avenue des Pins, Montreal, Quebec H3A IAI, Canada.

5–9 June. Toronto. *49th Annual Meeting of the Canadian Anaesthetists' Society.*
Information: Ms. Kara Kieferle, Meeting Coordinator. 1 187 Gerrard Street E, Toronto, Canada M5A 2E5.

7–12 June. Barcelona. *Anestesia 92.*
Information: Pacifico, S.A.: c/Muntaner, 112 08036-Barcelona, Spain.

9–12 June. Brussels, Belgium. *4th Joint Meeting, European and American Societies of Regional Anesthesia.*
Information: ESRA, Dr van Zundert, Kempenlaan 12, B-2300 Turnhout, Belgium or ASRA, PO Box 11086, Richard VA 23230-1086, USA.

10–12 June. Rotterdam, The Netherlands. *13th International Symposium on Computer Assisted Decision Support & Database Management in Anesthesia, Intensive Care and Cardiopulmonary Medicine.*
Information: Dr Omar Prakash, Thorax Centre, Erasmus University, 3000 DR Rotterdam, The Netherlands.

10–13 June. Brussels. *European Society of Regional Anaesthesia (UK) Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

11–14 June. Marco Island, Florida. *Annual Meeting of the Florida Society of Anaesthesiologists.*
Information: Florida Society of Anesthesiologists, 6501 25 Ways S, Ste D, St Petersburg, FL 33712, USA.

12–19 June. *The Hague, 10th World Congress of Anaesthesiology.*
Information: Dr Harm Lip, Nilantsweg, 99, 8041 AR Zwolle, Netherlands.

2–3 July. Bordeaux, France. *Tracheal Intubation.*
Information: Anne-Marie CROS, Department Anesthesie Reanimation, Hopital Pellegrin, Place Amelie Raba-leon 33076, Bordeaux Cedex, France.

12–16 August. Dunedin, New Zealand. *Intravenous and Inhalational Anesthesia.*
Information: Organizing Secretariat CANZ 1991, Department of Anaesthesia and Intensive Care, Dunedin Hospital, Dunedin, New Zealand.

19–21 August. Edinburgh. *VIIth Edinburgh Anaesthesia Festival.*
Information: Edinburgh Anaesthesia Festival, University Department of Anaesthetics, Royal Infirmary, Lauriston Place. Edinburgh EH3 9YW.

26–30 August. Poznan, Poland. *European Academy of Anaesthesiology (Open) Refresher Course and (Members only) Scientific Meeting.*
Information: Professor M.D. Vickers, Department of Anaesthesia, University of Wales College of Medicine, Health Park, Cardiff CF4 4XN.

2–4 September. Southampton. *Ultrasound Angiography 92. 2nd International Conference.*
Information: Conference Secretariat, Ultrasound Angiography 92, PO Box 15, Eastleigh, Hampshire SO5 5X9.

9–11 September. Bournemouth. *Linkman and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

14–16 September. Leicester. *4th Annual Meeting, University of Leicester.*
Information: Dr C.D. Hanning, Sleep Disorders Clinic, Leicester General Hospital, Leicester LE5 4PW.

14–18 September. Jerusalem, Israel. *5th International Congress, The Pain Clinic.*
Information: Secretariat, The Pain Clinic, PO Box 50006, 61500 Tel Aviv, Israel.

17–20 September. Halkidiki, Macedonia, Greece. *2nd Congress of Anaesthesiology and Intensive Medicine.*
Information: Secretariat, 2nd Congress of Anaesthesiology and Intensive Medicine, PO Box 10058, 54101 Thessaloniki, Greece.

1–2 October. London. *Continuing Medical Education and Training in Europe: the future.*
Information: Dr M.W.N. Nicholls or Mrs J.M. Coops, The Conference Office, c/o The Fellowship of Postgraduate Medicine, 6 St Andrew's Place, London NW1 4LB.

8–10 October. Mainz, Germany. *13th International Congress on Computers in Critical Care and Pulmonary Medicine.*
Information: Professor W. Dick Klinik fur Anathesiologie, Langenbeckstrabe 1, Postfach 3960, 6500 Mainz, Germany.

17–21 October. New Orleans. *American Society of Anesthesiologists Annual Meeting.*
Information: Executive Secretary, ASA, 515 Busse Highway, Park Ridge IL 60068, USA.

20–21 November. Brighton, UK. *1st CPR Congress of the European Resuscitation Council.*
Information: Dr D.A. Zideman, Department of Anaesthesia and Critical Care, Hammersmith Hospital, DuCane Road, London W12 OHS.

12–16 December. New York. *46th Postgraduate Assembly in Anesthesiology.*
Information: Kurt G. Becker, Executive Director, The New York State Society of Anesthesiologists, Inc., 41 East 42nd Street, Suite 1605, New York 10017, USA.

1993

30 January–6 February. Aspen, Colorado. *New Horizons in Anesthesiology.*
Information: Miss Kathleen A. Maitland, Department of Anesthesiology, Emory University at Crawford Long Hospital, 25 Prescott Street, 5404 Glenn, Atlanta GA 30308, USA.

12–16 February. Utah. *38th Annual Postgraduate Course in Anesthesiology — 'Anesthesiology: Today and Tomorrow'.*
Information: Vicky Larson, Department of Anesthesiology. University of Utah School of Medicine, 50 North Medical Drive, Salt Lake City, Utah 84132, USA.

12–15 March. Hong Kong. *7th Congress of the Western Pacific Association of Critical Care Medicine.*
Information: Secretariat, International Conference Consultants Ltd. Suites A & B, 16th Floor Casey Building, 38 Lok Ku Road, Sheung Wan, Hong Kong.

14–18 March. Cape Town, South Africa. *South African Society of Anaesthetists Jubilee Congress.*
Information: Mrs S. Elliot, Postgraduate Education Centre, UCT Medical School, Observatory 7925, Cape Town, South Africa.

19–23 March. San Diego, California. *67th Congress of the International Anesthesia Research Society.*
Information: Anne F. Maggiore, Executive Director, International Anesthesia Research Society, 2 Summit Park Drive, Suite 140, Cleveland, Ohio 44131, USA.

21–23 April. Sheffield. *Anaesthetists in Training Annual Scientific Meeting and Linkman Conference, Octagon Centre, Sheffied.*
Information: The Honorary Secretary of the Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

29 April–2 May. North Carolina. *Meeting of the Association of University Anesthetists.*
Information: Francis M. James III, Department of Anesthesia, Wake Forest University Medical Center, 300 S. Hawthorne Road, Winston-Salem, North Carolina 27103, USA.

10–13 June. Boca Raton, Florida. *Annual Meeting of the Florida Society of Anesthesiologists.*
Information: Florida Society of Anesthesiologists, 6501 25 Way Street, Ste D, St Petersburg, FL 33712, USA.

1–4 September. Liverpool. *European Course and Congress in Paediatric Anaesthesia.*
Information: Dr P.D. Booker, Alder Hey Hospital, Liverpool L12 2AP.

22–24 September. Glasgow. *Linkman Conference and Annual Scientific Meeting. Joint Meeting between the Association of Anaesthetists of Great Britain and Ireland, and the Canadian Society of Anaesthetists.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

9–13 October. Washington DC. *American Society of Anesthesiologists Annual Meeting.*
Information: Executive Secretary, ASA 515 Busse Highway, Park Ridge, IL 60068, USA.

1994

7–9 September. Brighton. *Linkman Conference and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

2–7 October. Jerusalem. *European Congress of Anaesthesiology.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

1995

13–15 September. Birmingham. *Linkman Conference and Annual Scientific Meeting.*
Information: The Honorary Secretary, Association of Anaesthetists of Great Britain and Ireland, 9 Bedford Square, London WC1B 3RA.

Anaesthesia, 1992, Volume 47, page 367

Hazard notice

Y-Can Cannulae manufactured by H.G. Wallace Ltd., Produce Recall: Code 23G-YC233Y-Batch 161091. HC(Hazard)(91)41.

Following reports of a hole in the side arm tubing of two cannulae, the manufacturer has recalled all Code 23G–YC 23SY cannulae belonging to batch 161901. Replacement will be free of charge.

Graseby Medical Ltd. PCAS syringe pump. Modification update. HC(Hazard)(91)42.

This notice follows HC(91)40. Graseby believe they have identified the cause of the incident and have designed a modification to prevent its recurrence. Users are advised to have all PCAS pumps modified before returning them to normal use.

Safety Action Bulletin

Ohmeda APL (Adjustable Pressure Limiting) Valves: Risk of failure. SAB (92)3

Plastic type There have been reports of failure of this APL valve due to application of excessive torque during adjustment of the pressure control. Turning the knob when it is stiff may result in the valve assembly unscrewing from its housing, or for it to shear within the central core. This valve is unsuitable to be sterilised by autoclaving.

Metal type There have been reports of this valve causing inadvertent PEEP and airway pressure should be monitored during use.

Anaesthesia, 1992, Volume 47, page 368

Errata

Anaesthesia, 1992, Volume 46, page 1090

Safe use of propofol in a patient receiving tranylcypromine

R.A. HYDE AND A.J. MORTIMER

The references from the above letter were omitted, and are now included below.

[1] POWELL H. Use of alfentanil in a patient receiving monoamine oxidase inhibitor therapy. *British Journal of Anaesthesia* 1990; **64:** 528.
[2] *British National Formulary* 1991; **21:** 146.
[3] ROUSE EC. Propofol for electroconvulsive therapy. A comparison with methohexitone. Preliminary report. *Anaesthesia* 1988; **43** (Suppl): 61–4.

Anaesthesia, 1991, Volume 46, pages 1036–1038

Reversal of prolonged suxamethonium apnoea with fresh frozen plasma in a 6-week-old infant

R. S. GILL, N. O'CONNELL AND R. P. F. SCOTT

Corrections to errors in the reference list to the above paper are given below. References 1 and 2 were not actually quoted in the paper; their place should be taken by Knedel and Bottger and Varley *et al.* which were erroneously listed as references 3 and 4 respectively.

In addition, in the Disccussion at the end of the first paragraph reference 18 is incorrectly cited; the correct reference is 8.

Notice to contributors to *Anaesthesia*

Manuscripts will be reviewed for possible publication on the understanding that they are being submitted to one journal at a time and have not been published, simultaneously submitted, or already accepted for publication elsewhere. This does not preclude consideration of a manuscript that has been rejected by another journal or of a complete report that follows publication of preliminary findings elsewhere, usually in the form of an abstract. Investigations performed on man must conform to appropriate ethical standards including voluntary, informed consent and acceptance by an ethics committee. Articles accepted become copyright of *Anaesthesia.*

Contributors are requested to submit two copies of manuscripts. They are also advised to retain a third copy as the Editors cannot accept responsibility for the loss of manuscripts in the post. The covering letter should be signed personally by all the authors. Articles should be forwarded to:

Dr M. Morgan, Department of Anaesthetics, Royal Postgraduate Medical School, Hammersmith Hospital, London W12 0HS, UK.

PREPARTION OF MANUSCRIPTS

Articles for *Anaesthesia* should be prepared in accordance with *Uniform requirements for manuscripts submitted to biomedical journals* (*British Medical Journal* 1979; **1:** 532–5) except that the titles of journals in the reference section should be given in full (see below). A reprint of these requirements of which this notice is a summary, can be obtained from the *British Medical Journal* price 50 pence (UK).

Type manuscripts on white bond paper; 20.3 × 26.7 cm or 21.6 × 27.9 cm (8 × 10½ in. or 8½ × 11 in.) or ISO A4 (212 × 297 mm) with margins of at least 2.5 cm (1 in.). Use double, and preferably triple, spacing throughout, including the references. Please do not use a dot matrix printer, particularly one with poor quality descenders or ascenders. Unseparated, fan-folded manuscripts may be returned to the author. *The manuscript* should consist of the following sections in this order each beginning on a new page: *title page, summary* and *key words, text, acknowledgements, references, individual tables,* and *legends for figures.*

Number pages consecutively, beginning with the title page.

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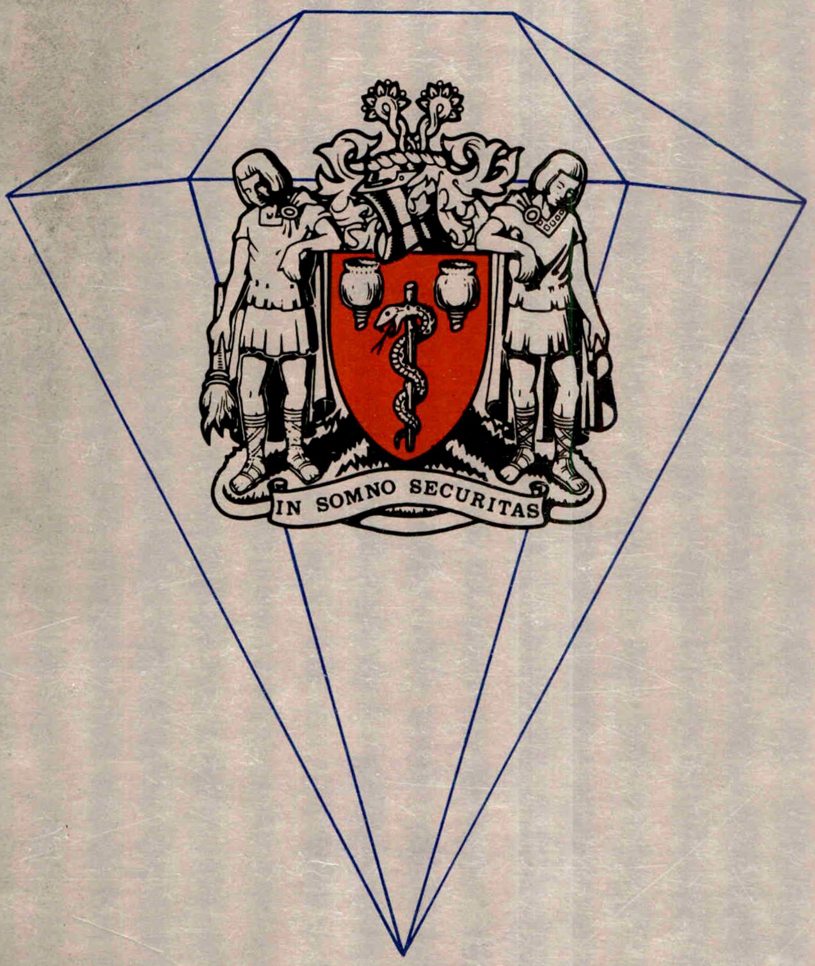

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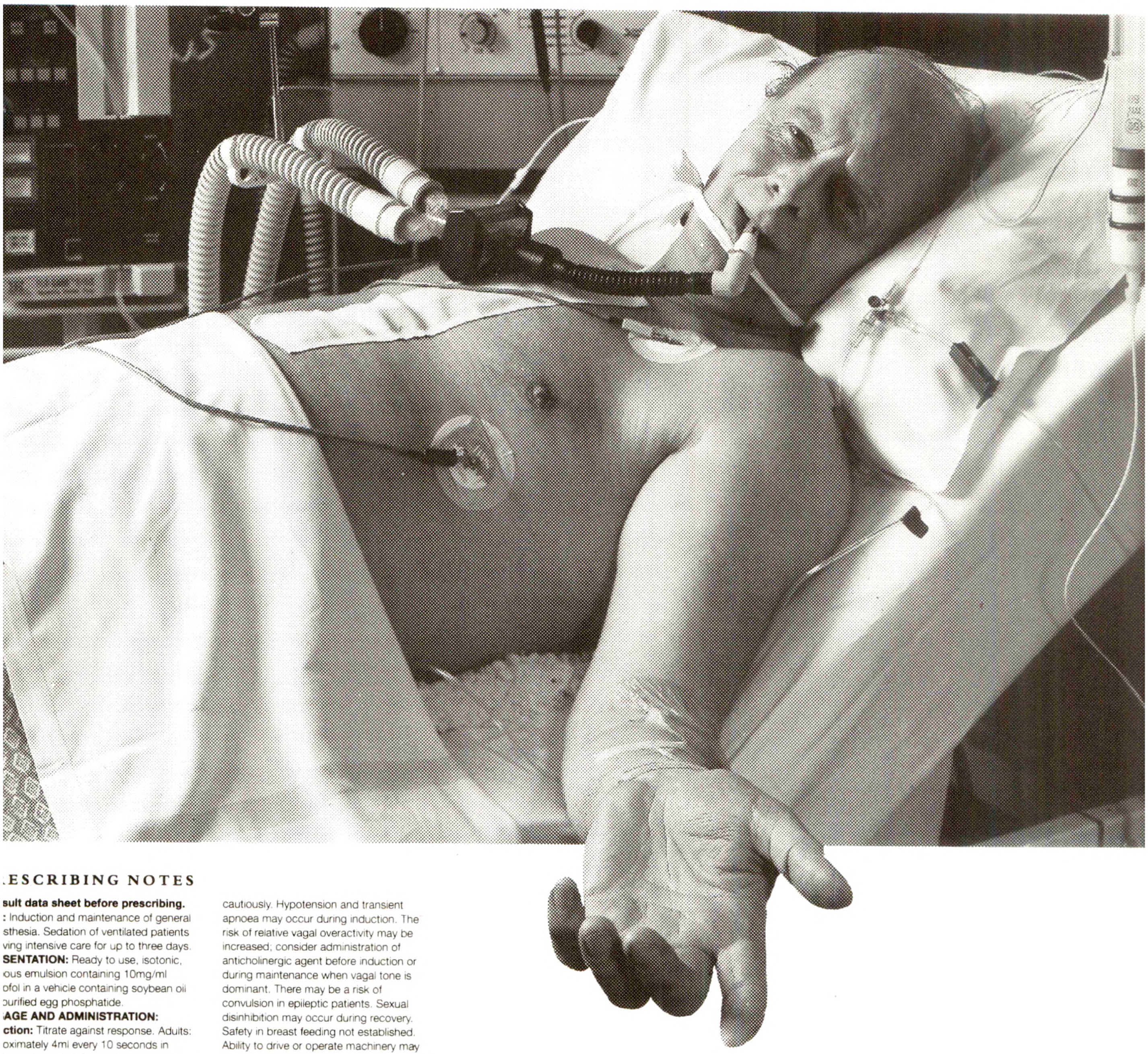

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Anaesthesia, 1992, Volume 47, pages 369–370

Editorial

'Forward together'

Annus Domini nineteen hundred and ninety-two is for anaesthetists a year of celebration and gratitude. In January there was the golden jubilee of Harold Griffith's demonstration of the use of curare in Montreal and 1 July marks the Diamond Jubilee of the foundation of the Association of Anaesthetists of Great Britain and Ireland. The Association celebrated with a special Winter Scientific Meeting. Her Royal Highness Princess Margaret opened the proceedings and graciously accepted Honorary Membership of the Association. A carefully researched history, subtitled 'Sixty years of Progress and Achievement' has been written by Dr Tom Boulton, a past President, to whom the writer is indebted. It is appropriate that a brief review of the origins of the Association as well as its past influence and future prospects should be reviewed in this jubilee issue of its journal.

From its discovery in 1842–46, progress in anaesthesia both in respect of scientific advance and status of its practitioners was slow compared with that of other branches of medicine. It might fairly be described as arithmetical, along a straight line with a pretty shallow slope. Suddenly, in the last decade of the nineteenth century, there was a change: the slope became exponential. Many factors account for this, but, unquestionably, a major determinant has been the formation of active and progressive societies of anaesthetists, and in that Dr John William Frederick Silk played the key role.

Silk was an Assistant Anaesthetist of Guy's Hospital, London, a man of considerable distinction, but 'envious time' has been unfair to him, for he is now largely forgotten. He recognised that anaesthetists needed a forum in which to exchange views and plan the future of the specialty. In 1893, with 40 colleagues, he founded the first 'Society of Anaesthetists' in the world [1]. It is a nice coincidence that the Society met in the Medical Society of London's rooms in Chandos Street, in which the Association was to begin its own story 39 years later. The Society thrived and was active for 14 years. Not only were influential papers read before it, but it also took the first steps towards improving the teaching of anaesthesia in medical schools and in raising the status of its teachers.

In 1907, the majority of the London medical societies came together to form the Royal Society of Medicine (RSM). The London Medical Society held out as did the Society of Anaesthetists, but the latter only for a year; in 1908, it became the Anaesthetic Section of the Royal Society of Medicine. Chivalry accounted for the delay; it was due to insistence that 'The rights of lady members be preserved' [1]. One observes with some embarrassment that, after 60 years, the Association still awaits the election of a woman President!

The Royal Charter of the RSM does not permit any activity other than academic and, by 1932, a new and politically minded generation of anaesthetists formed the Council of the Anaesthetic Section. A past President of the Section, Henry Featherstone of Birmingham, was irked by the inability of the section to indulge in political action in furtherance of the interests of the practising anaesthetist. After discussion with colleagues, he wrote to 100 anaesthetists on the staff of the main teaching hospitals, both in the United Kingdom and also in the Irish Free State, inviting them to a meeting, the purpose of which was to form a new and free body of anaesthetists. The meeting was held in April 1932 and, although the attendance was not great, the letters of apology indicated wide support for the proposal. The inaugural meeting of the Association of Anaesthetists of Great Britain and Ireland was held on 1 July 1932. Featherstone was elected President.

Many achievements bear witness to the influence of the Association on the development of anaesthesia over these 60 years. Within 3 years, the examination for a Diploma in Anaesthetics was established. Recognition by government of the role of the Association came in 1940, when a representative of the Association was invited to serve on the Central Medical War Committee. One wonders how many specialist anaesthetists, in the services during the war, have appreciated that their rank of major, or its equivalent in the Royal Navy and Air Force, was the consequence of the acceptance by the War Office of the Association's definition of a 'specialist anaesthetist'. The Association also advised both government and local authorities on the appropriate anaesthetic staffing in the Emergency Medical Service and local authority hospitals. It has made many contributions to patient safety by continued education of its members, by fostering and financing research and by medical audit. A major step forward was the publication, in 1946, of the Journal, *Anaesthesia*, under the editorship of Langton Hewer. On the international scene it was involved, from the start, in the formation of the World Federation of Societies of Anaesthesiologists. Sir Geoffrey Organe, then President, was elected as the first Secretary General of the WFSA and it was largely he who persuaded the American Society of Anesthesiologists, initially not a member, to enrol in the Federation in 1960. The first European Conference, although held in Vienna in 1962, was initiated by the Association.

After the war came the National Health Service and with it concern as to the future status of anaesthesia in the hospital service. It is fortunate that A.D. Marston, President from 1944 to 1947, was an astute, persuasive and influential politician. With the help of another such, his friend Sir Alfred (later Lord) Webb-Johnson, he was able to steer the specialty through very troubled waters. It is difficult for anaesthetists of today to appreciate the angst that prevailed in the profession in those days, not least in anaesthesia. For many anaesthetists in civilian practice their future looked very uncertain and a specialist anaesthetist in the armed services, who had not held a hospital anaesthetic post before the war, on demobilisation could not see any defined future in respect of the terms of service in the new NHS. There was an influential body of medical and surgical opinion which considered that the great majority of qualified anaesthetists

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should be in a sub-consultant grade. As late as 1948 a distinguished physician with the responsibility for suggesting the grade of all specialists in his region, recommended that three anaesthetists only should be given consultant status! Fortunately, with the help of the Association and its friends, his view was changed.

Webb-Johnson took steps to resolve this situation and invited the Association to nominate a representative to serve as a co-opted member on the Council of the College. Marston was nominated. Already one Faculty, that of Dental Surgery, was in process of formation and Webb-Johnson and Marston saw this as a way forward for anaesthesia. He suggested that the Association should apply to the Council of the College for the formation of a Faculty of Anaesthetists. The President of the Association, John Gillies, summoned a Special General Meeting of the Association to discuss this proposal. It was held on 6 February 1948 [2]. There was an excellent attendance and an acute perception that anaesthesia was at a cross roads. Loyal Association members could see that the educational and other aspects of the work of the Association might be at stake and, moreover, anaesthesia might appear subordinate to surgery, as had been the case for too long. Marston, Bernard Johnston, an anaesthetic colleague of Webb-Johnson at the Middlesex Hospital, and the younger generation were, however, persuasive in maintaining that anaesthesia desperately needed friends and full support from the surgeons. Although the examination for the DA had been upgraded, the carrot of a Fellowship by examination in a Royal College was decisive. The resolution to apply for a Faculty was carried unanimously.

Thus, the Association may justifiably take some pride in the many achievements of the Faculty which have resulted in an academic status and professional standing for anaesthetists as high as that of any branch of the profession. The more so perhaps because there was considerable overlap in the membership and officers of the governing bodies of the Association and Faculty, a feature desirable and necessary at the time, but perhaps less so now.

It is not difficult to see that the Association has played an important part in the decision of the Faculty to seek collegiate status. Ten years ago, at the time of the golden jubilee of the Association, the President wrote an editorial in this journal which outlined the steps whereby the Faculty was evolving to independence and he presented options for progress, pointing out that the Council had 'consistently maintained pressure for change': that pressure, he recorded, had gone so far as to influence the composition of the Board of Faculty [3]. *Res ipsa loquitur!*

The final break with the Royal College of Surgeons came with the appreciation that a College within another College, an option favoured by many, cannot in the eyes of the Privy Council be truly independent and therefore would not be eligible for the 'Royal' prerogative. This distinction is most desirable and fortunately the break has been achieved without forfeiture of a friendly relationship with the surgeons. There will, however, be many anaesthetists, including the writer, who are sad that severance was necessary from an academic body of such standing and tradition as the Royal College of Surgeons which, they remember, so effectively supported the specialty at probably the most threatening period in its history.

That is all past: any rancour has evaporated and both Association and College must look to the future. The Association, whilst closely cooperative with the College, must remain separate and independent. The College, like the Faculty, will have the status of a registered charity. It will obviously further the interests of anaesthetists and the specialty in very many ways, but not in those which might be frowned on by the Charities Commission. The Association, it is hoped, will continue to promote the interests of its members by its very successful educational seminars in the Association's fine new home in Bedford Square (itself a milestone) and by its concern for their financial welfare, its audit of mortality and morbidity, its compassionate care for the sick anaesthetist and its collaboration with many bodies also protective of the safety of the patient, such as the Medical Defence Societies and British Standards Authority.

There is much to be done and maybe all danger is not past. There is a radically new situation in the Health Service and its mandarins may not, at first, always be appreciative of the huge importance of maintaining standards in education, in staffing and in equipment for a specialty so critical in its ministrations as anaesthesia; especially may this be so when resources, both of manpower and finance, are tight. It is very important to have two fraternal and mutually supportive bodies, each free and competent in its own sphere of action, to monitor the situation.

The writer is sure that all those practising in collaborative and dependent specialties will wish to join with members in congratulating the Association, in thanking its Officers and Council and supportive staff, past and present, for 60 such fruitful years and in responding enthusiastically to the ancient and beneficent wish for the future: *'Ad multos annos.'*

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Editorial notices

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Anaesthesia, 1992, Volume 47, pages 371–375

Upper oesophageal sphincter pressure and the intravenous induction of anaesthesia

R. G. VANNER, B. J. PRYLE, J. P. O'DWYER AND F. REYNOLDS

Summary

The upper oesophageal sphincter can prevent regurgitation of oesophageal contents into the pharynx following gastro-oesophageal reflux in the awake patient. Upper oesophageal sphincter pressure was recorded with a Dent sleeve after hypnosis with midazolam ($n = 7$) and also during the rapid intravenous induction of anaesthesia with thiopentone ($n = 16$) or ketamine ($n = 7$). Thiopentone decreased mean(SD) sphincter pressure from an awake value of 43(19) to 9(7) mmHg ($p < 0.001$) and midazolam from 38(25) to 7(3) mmHg ($p < 0.02$). Mean(SD) sphincter pressures before and after ketamine were not significantly different at 29(15) and 32(21) mmHg respectively. After suxamethonium mean(SD) sphincter pressure in all patients ($n = 30$) was 7(4) mmHg. Laryngoscopy ($n = 30$) caused a small increase in mean(SD) sphincter pressure to 13(10) mmHg ($p < 0.001$). Thiopentone caused a rapid fall in upper oesophageal sphincter pressure which usually started before loss of consciousness. These findings have implications for the timing of cricoid pressure application.

Key words

Gastrointestinal tract; upper oesophageal sphincter.
Tracheal intubation; cricoid pressure.
Complications; regurgitation, aspiration.

The upper oesophageal sphincter is formed by the lamina of the cricoid cartilage anteriorly and striated muscle posteriorly, creating a high pressure zone 3 cm long with a crescent-shaped lumen. The major component of the striated muscle is cricopharyngeus, which is attached to the lateral aspects of the cricoid cartilage and joins its opposite side, without a median raphe, like a sling. The cricopharyngeus is under a complex motor nerve supply from the medulla, via the pharyngeal plexus, which controls both its muscle tone and its reflex relaxation during swallowing, belching and vomiting. The muscle tone of cricopharyngeus creates a sphincter pressure, which increases slightly during inspiration [1], preventing the entry of air into the oesophagus and the regurgitation of oesophageal contents into the pharynx of the awake patient. The upper oesophageal sphincter can also prevent the regurgitation of oesophageal contents during light general anaesthesia in the absence of neuromuscular blockade [2, 3].

Suxamethonium usually causes an abrupt fall in upper oesophageal sphincter pressure (UOSP) with the onset of fasciculations [4]. In those patients at risk of gastro-oesophageal reflux, cricoid pressure counteracts this reduction in UOSP [5]. However, there is controversy about when cricoid pressure should be applied: before loss of consciousness [6, 7], or only after loss of consciousness [8, 9] in case vomiting is provoked by its application.

UOSP is about 40 mmHg when awake but is not constant and varies with the state of arousal [10], increasing with mental stress [11] and decreasing to a mean of 8 mmHg during deep sleep [12]. Although intravenous pentobarbitone decreases UOSP in dogs [13] the effects of anaesthetic drugs have not been previously studied in humans. We have recorded UOSP after hypnosis with midazolam and also during induction of anaesthesia with intravenous thiopentone and ketamine. UOSP was measured continuously by a manometry catheter with a Dent sleeve. The first 26 patients in this study also took part in a study of cricoid pressure [5].

Method

Measurement of UOSP

The Dent sleeve [14] is a 4.0 mm diameter manometry catheter with a 3 mm wide and 6 cm long sleeve on one side. The sleeve is a collapsible silicone rubber membrane

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which, when perfused with water through a transducer, performs as a Starling resistor, measuring the highest pressure applied along its length [15]. The upper oesophageal sphincter has a radial asymmetry in its pressure profile [16] and by convention the sleeve is positioned so that it faces posteriorly in the sphincter and it can then be used to measure sphincter pressure continuously [17]. The manometry catheter also has a perfused side-hole sensor at the distal end of the sleeve. After inserting the catheter into the oesophagus the position of the upper oesophageal sphincter was first identified by slowly withdrawing the side-hole sensor across the high pressure zone, before repositioning the catheter with the sleeve facing posteriorly and straddling the sphincter. The side hole, now positioned below the sphincter, was then used to measure oesophageal pressure. The catheter was perfused with water through a low compliance system with 0.6 ml.min^{-1} through the sleeve and 0.2 ml.min^{-1} through the side hole. UOSP and oesophageal pressure were measured by two calibrated transducers. The catheter was zeroed to a level behind the cricoid cartilage before insertion and checked after removal. When perfused at this rate the sleeve had a response time of 5 s to a decrease in pressure of 50 mmHg.

The procedure

Ethics committee approval was obtained and 30 patients, ASA 1 and 2, gave informed consent. The patients were recruited from those that required tracheal intubation during anaesthesia for elective surgery. One hour after premedication with intramuscular papaveretum and hyoscine the manometry catheter was swallowed via an anaesthetised nostril, and positioned as described above. The patient then lay on a standard pillow of 6.0 cm of firm foam rubber with an integral firm neck support to hold the head and neck in a standard intubating position as UOSP may vary with head and neck position. The patients' lungs were pre-oxygenated and the awake UOSP was recorded 2 min later.

UOSP was recorded continuously as thiopentone 4.0 mg.kg^{-1} ($n = 16$) or ketamine 2.0 mg.kg^{-1} ($n = 7$) was injected into a large forearm vein over 4 s. Loss of consciousness after thiopentone was timed to the loss of the eyelash reflex, but after ketamine the timing was more subjective. The recording was continued until 30 s after loss of consciousness. Suxamethonium 1.0 mg.kg^{-1} was then given and UOSP noted 1 min later before tracheal intubation. Another seven patients received midazolam 0.05 mg.kg^{-1} intravenously and UOSP was recorded 2 min later, before inducing anaesthesia. At laryngoscopy, using a Macintosh laryngoscope, the UOSP was recorded in all 30 patients before tracheal intubation.

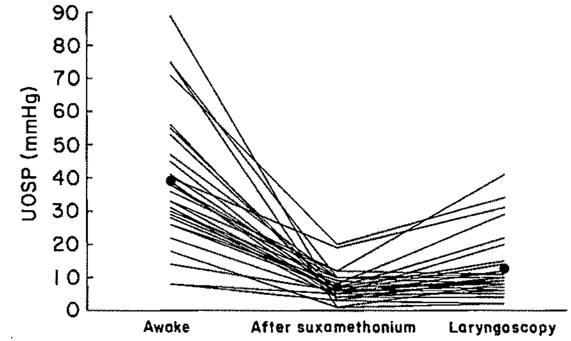


Fig. 1. Upper oesophageal sphincter pressure (UOSP) awake, 1 min after suxamethonium and during laryngoscopy in each of 30 patients. The round symbols represent the mean values.

Statistics

The paired *t*-test was used to assess the significance of a change in UOSP within the drug groups. The non-paired *t*-test was used to compare baseline awake values of UOSP between the groups. Linear regression analysis was used to relate dose of papaveretum to awake UOSP.

Results

Patient details are shown in Table 1. The sleeve pressure was always higher than oesophageal pressure, the latter usually varied between 0 and 5 mmHg. The sleeve pressure therefore represented UOSP and not oesophageal pressure. Figure 1 shows awake UOSP in each patient; two patients had an unusually low awake UOSP of 8.0 mmHg; both were drowsy following premedication. Although one of them received the largest dose of papaveretum (0.27 mg.kg^{-1}), overall there was no correlation between UOSP awake and the dose of papaveretum in mg.kg^{-1} ($p = 0.5$). The mean awake UOSP in all patients was 39 mmHg (with 95% confidence limits of 31–46) and there was no difference between the groups ($p > 0.1$) (Table 2). The mean UOSP recorded 1 min after suxamethonium in all patients was 7 mmHg (with 95% confidence limits of 5.6–8.9) (Fig. 1). This residual pressure was significantly lower than UOSP while awake ($p < 0.001$). Laryngoscopy caused a small rise in UOSP ($p < 0.001$) to a mean of 13 mmHg (Fig. 1).

The effects of thiopentone, ketamine, midazolam and suxamethonium on mean UOSP are shown in Table 2 and Figure 2. One minute after receiving midazolam all seven patients were asleep. The UOSP in each patient receiving thiopentone or ketamine is shown in Figure 3. Thiopentone decreased UOSP ($p < 0.001$), as did midazolam ($p < 0.02$),

Table 1. Patient details; mean (range).

	Thiopentone	Ketamine	Midazolam	Total
n	16	7	7	30
No. female	9	4	3	16
No. premedicated	14	7	5	26
Papaveretum; mg.kg^{-1}	0.19 (0.14–0.27)	0.18 (0.15–0.22)	0.19 (0.14–0.23)	0.19
Age; years	45 (33–56)	43 (33–55)	50 (37–64)	46
Weight; kg	69 (52–110)	67 (55–87)	73 (63–100)	70
Time to loss of consciousness; s	20 (16–29)	38 (21–60)	—	—

Table 2. Upper oesophageal sphincter pressure (UOSP); mmHg, mean (SD).

	Thiopentone	Ketamine	Midazolam	Total
n	16	7	7	30
UOSP awake	43 (19)	29 (15)	38 (25)	39 (20)
UOSP at loss of consciousness	26 (13)	36 (21)	—	—
UOSP 30 s after loss of consciousness	9 (7)	32 (21)	7 (3)	—
UOSP 1 min after suxamethonium	8 (5)	7 (3)	6 (3)	7 (4)

but ketamine did not alter mean UOSP from awake values. UOSP after suxamethonium was not significantly different from that after thiopentone ($p = 0.4$) or after midazolam ($p = 0.5$), but after ketamine, suxamethonium caused a significant fall ($p = 0.02$).

The decrease in mean UOSP following thiopentone is shown in more detail in Figure 4. Mean UOSP started to decrease before loss of consciousness and the most rapid fall was in the 5 s before loss of consciousness. Five of the 'thiopentone' patients showed marked fluctuation of UOSP with respiration for about 15 s before loss of consciousness, increasing with inspiration and decreasing with expiration; these lower pressures during expiration were responsible for the early fall in mean UOSP at 10 and 15 s before loss of consciousness. At loss of consciousness, 11 of these patients showed a marked decrease in UOSP (see Fig 3). In all cases the rate of fall of UOSP was slower than the response time of the Dent sleeve.

Ketamine was not given to hypertensive patients. Those patients who had ketamine received midazolam after the study but before emergence; on direct questioning no patients had unpleasant dreams or hallucinations postoperatively.

Discussion

Gastro-oesophageal reflux is a normal physiological consequence of a full stomach; gastric distension causes a frequent reflex relaxation of the lower oesophageal

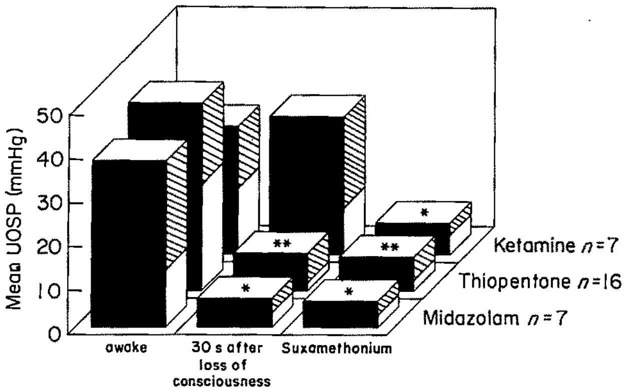


Fig. 2. Mean upper oesophageal sphincter pressure (UOSP) awake, 30 s after loss of consciousness and 1 min after suxamethonium in the three drug groups. The hatched areas are 1 SD below the mean. The p values represent a significant decrease in UOSP from the awake value: $^{*}p < 0.02$, $^{**}p < 0.001$.

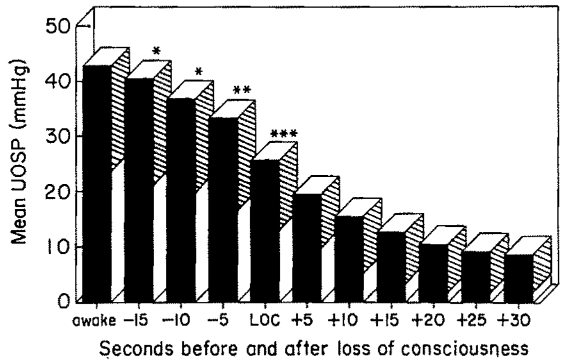
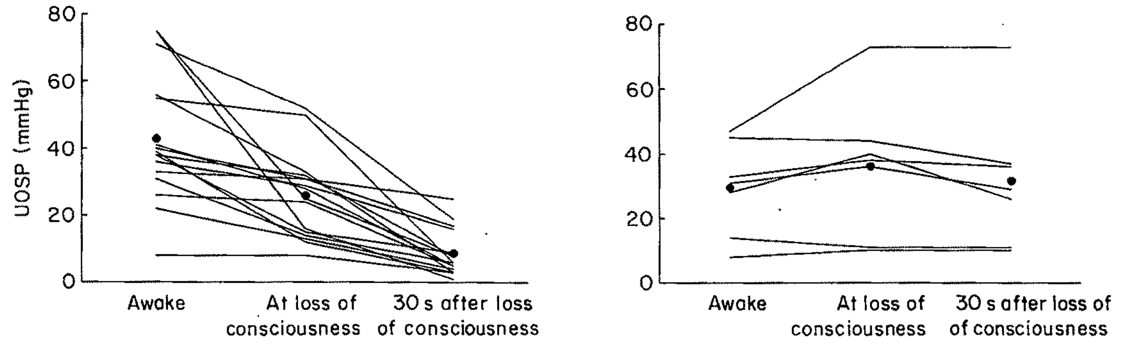


Fig. 4. Mean upper oesophageal sphincter pressure (UOSP) in the 16 patients who received thiopentone, awake and at 5 s intervals before and after loss of consciousness. The hatched areas are 1 SD below the mean. The p values represent a significant decrease in UOSP from the awake value: $^{*}p < 0.05$, $^{**}p = 0.02$, $^{***}p = 0.001$.



Thiopentone n=16

Ketamine n=7

Fig. 3. Upper oesophageal sphincter pressure (UOSP) awake, at loss of consciousness and 30 s after loss of consciousness in each patient in both the thiopentone and ketamine groups. ●, mean values.

sphincter allowing spontaneous reflux [18]. During spontaneous gastro-oesophageal reflux the oesophageal pressure usually rises abruptly by 5–10 mmHg when the lower oesophageal sphincter relaxes and oesophageal pressure equals gastric pressure with the development of a common cavity [19]. The highest gastric pressure recorded in the supine position is 25 mmHg [20] and therefore gastric contents that reflux spontaneously into the oesophagus before induction of anaesthesia may occasionally reach this pressure. Regurgitation does not normally occur, however, as the UOSP when awake is usually high enough to prevent it, but regurgitation has been shown to occur if UOSP is below 25 mmHg [21]. Although the mean UOSP of our awake patients was 39 mmHg, in six (20%) it was below 25 mmHg.

It is possible that the presence of the manometry catheter caused an increase in cricopharyngeal muscle tone and artificially increased UOSP. Jacob *et al.* [13] showed in the dog that cricopharyngeal electromyographic (EMG) activity increased with the passage of a similar manometry catheter and, although adaption did occur immediately after positioning, the EMG activity did not return to the baseline level. However, in the present study the mean awake UOSP of 39 mmHg is similar to that recorded in other studies [10–12].

This study has shown that intravenous thiopentone, midazolam and suxamethonium can all decrease mean UOSP to less than 10 mmHg, a level that could allow the regurgitation of oesophageal contents into the pharynx. The residual UOSP after suxamethonium was not statistically lower than after thiopentone or midazolam, indicating that the upper oesophageal sphincter was almost fully relaxed after these drugs. These results confirm the hypothesis of Kahrilas *et al.* [12] that their mean UOSP of 8 mmHg recorded (with similar methodology) during deep sleep, represents residual UOSP. Studies in the opossum [22] have shown a residual UOSP of 13 mmHg after tubocurarine and also after section of the motor nerve to cricopharyngeus. Studies in the dog [13] have also shown a residual UOSP of 13 mmHg during periods of absent cricopharyngeal EMG activity. These authors have suggested that this residual pressure is caused by elastic tissue in the neck, as it only falls to zero when the upper oesophageal sphincter actually opens with the movement of the larynx during swallowing [22]. After induction of anaesthesia with a 'thiopentone-relaxant technique' Mucklow and Larard [23] noticed that regurgitation occurred with either inflation of the lungs or with laryngoscopy, and suggested that anterior movement of the larynx with laryngoscopy caused cricopharyngeal incompetence. In the present study, however, the low residual UOSP after suxamethonium was not further reduced during laryngoscopy with a Macintosh laryngoscope.

Thiopentone caused a rapid fall in UOSP which usually started before loss of consciousness. The decrease in UOSP with thiopentone occurred in two stages: firstly, an early decrease caused by increased fluctuation of UOSP with respiration in five patients; secondly, a progressive decrease in UOSP starting a few seconds before loss of consciousness to reach the lowest level 30 s after loss of consciousness. The electromyogram relates to muscle tone and may explain this response: in the opossum [22], the EMG activity of cricopharyngeus varied with the respiratory cycle, during light anaesthesia with pentobarbitone the variation with respiration was more obvious and deep anaesthesia caused a marked reduction in activity; in the dog [24], deep anaesthesia with thiopentone to abolish the glottic reflex abolished cricopharyngeal EMG activity; thiopentone in humans has been shown to decrease EMG activity in upper airway muscles and also to change EMG activity from a tonic pattern to activity in phase with inspiration [25].

Ketamine anaesthesia increases skeletal muscle tone and when given to the rabbit the EMG activity of the upper airway muscles is maintained [26]. We have shown that ketamine maintains UOSP in humans. Although ketamine 1 mg.kg^{-1} has been compared favourably to thiopentone 3–4 mg.kg^{-1} for the intravenous induction of anaesthesia for Caesarean section [27, 28], it has been suggested that the slower onset of action makes ketamine less suitable [29]. As ketamine does not reduce UOSP it could be useful for the induction of anaesthesia in patients at risk of gastro-oesophageal reflux. However, as ketamine, like conventional anaesthetics, depresses laryngeal reflexes [30] it should be followed by tracheal intubation in these patients.

We have shown that patients who are heavily sedated after intravenous midazolam have a low UOSP and are at risk of regurgitation. Intravenous benzodiazepines also depress laryngeal reflexes [31]. Therefore patients at risk of gastro-oesophageal reflux should not be sedated as the pulmonary aspiration of gastric contents may occur. However, intravenous benzodiazepines are currently popular in the initial management of eclampsia; these patients are therefore in danger of pulmonary aspiration and should be managed accordingly [32].

During the induction of anaesthesia with thiopentone, in patients at risk of reflux, cricoid pressure should be applied whilst awake to counteract the fall in UOSP before loss of consciousness, thus maintaining UOSP above the pressure of oesophageal contents to prevent regurgitation into the pharynx. We previously reported that in anaesthetised and paralysed patients a cricoid force of 40 Newtons increased UOSP to above the median of the awake values in all patients [5]. This level of cricoid pressure is uncomfortable and vomiting has followed its application resulting in death from aspiration pneumonitis in one patient [33], and rupture of the oesophagus in another [34]. Only 14 of 22 colleagues could tolerate 40 Newtons of cricoid force for 20 s; although all 22 subjects could tolerate 25 Newtons for that time, 19 were uncomfortable and one wanted to retch [35]. Clearly a compromise has to be made. Sellick originally recommended that, as thiopentone is injected, cricoid pressure is applied with light pressure [36] or with moderate pressure [6], until loss of consciousness when firm pressure is applied. As cricoid pressure compresses cricopharyngeus [5], the effects of both cricoid pressure and cricopharyngeal muscle tone must summate to give a higher UOSP before loss of consciousness than cricoid pressure alone, as the muscle does not completely relax until after loss of consciousness (Fig. 4). A moderate cricoid force of 20 Newtons should therefore maintain UOSP before loss of consciousness. During induction of anaesthesia with ketamine, however, cricoid pressure can be applied lightly before loss of consciousness; as ketamine maintains UOSP, cricoid pressure should then be applied firmly with suxamethonium administration and continued until after tracheal intubation has been completed.

Acknowledgments

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Intra-operative patient-controlled sedation

Comparison of patient-controlled propofol with patient-controlled midazolam

G. E. RUDKIN, G. A. OSBORNE, B. P. FINN, D. A. JARVIS AND D. VICKERS

Summary

Propofol and midazolam were compared for intra-operative patient-controlled sedation in 40 ASA 1 day patients undergoing surgical extraction of third molar teeth under local anaesthesia. All patients initially received 0.7 $\mu g.kg^{-1}$ fentanyl. Patients in the propofol group self-administered 20 mg (2 ml over 6 s) bolus doses of propofol; successful demands averaged 8.0 (SD 4.4) and unsuccessful demands (during the 1 min lockout period) 2.8 (SD 4.1). The midazolam group self-administered 0.5 mg (2 ml over 6 s) bolus doses and averaged 14.0 (SD 6.3) and 17.6 (SD 19.8) successful and unsuccessful demands respectively. Postoperative memory, measured with delayed free recall, and postoperative mental performance, measured with the frequency accrual speed test index, were both significantly less impaired in the propofol group. Although there was no significant difference in patient satisfaction, measured postoperatively, propofol was judged the more suitable agent for patient-controlled sedation, because of its more rapid response to fluctuating intra-operative requirements, superior recovery characteristics and beneficial effect on mood.

Key words

Hypnotics, benzodiazepines; midazolam.
Anaesthetic techniques; patient-controlled sedation.
Anaesthesia, outpatient; dental.
Anaesthetic intravenous; propofol.

Intra-operative patient-controlled sedation (PCS) with propofol has been shown to provide safe and effective sedation for the surgical extraction of third molar teeth [1] that compares favourably with a standard sedation technique using divided doses of midazolam and fentanyl [2].

The patient-controlled pump used in the earlier work with propofol [1,2] took over 2 min to deliver bolus doses of 0.7 $mg.kg^{-1}$ (propofol 10 $mg.ml^{-1}$), at a maximum infusion rate of 100 $ml.h^{-1}$. Thus, with a lockout period of 1 min, patients could not self-administer more often than once every 3–4 min. In order to explore optimal patient-control parameters for intra-operative sedation, we assembled a new programmable patient-controlled pump capable of bolus delivery at 1200 $ml.h^{-1}$ (20 $ml.min^{-1}$). This study describes the use of this pump to compare propofol and midazolam for PCS during the extraction of third molar teeth under local anaesthesia.

The high lipid solubility of midazolam at physiological pH allows for rapid brain entry [3] and relatively fast onset of action. Its use has been reported for patient-controlled anxiolysis pre-operatively [4] and in intensive care [5] and in combination with fentanyl it has been used for PCS during surgical procedures carried out under epidural anaesthesia [6]. However, sedation requirements in these circumstances are usually less rigorous than those for oral surgery, in which patient needs often fluctuate rapidly. It was decided therefore to compare propofol and midazolam with regard to their suitability for the PCS technique during the extraction of third molar teeth under local anaesthesia.

Patients and methods

The study had the approval of the Human Ethics Committee at the Royal Adelaide Hospital.

Patient-controlled pump

The patient-controlled pump was assembled by interfacing a programmable infusion pump (Ohmeda model 9000

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syringe pump; Ohmeda, West Yorkshire, UK) with a personal computer (Epson model PCe; Seiko Epson Corporation, Nagano, Japan) fitted with two serial RS232 I/O ports. The software necessary to drive the pump was written in BASIC (Microsoft Quickbasic Version 4.5; Microsoft Corporation, Redwood, Washington State, USA). All communications were validated with checksum parity error checking. One computer I/O port accepted patient demands made through a modified computer mouse device triggered by a pressure-sensitive switch that was activated by a commercial hand-held pneumatic control (Graseby Medical Ltd, Watford, UK). When the pneumatic control activated the pressure-sensitive switch an audible tone was generated to indicate that the request had been sent to the pump. The second I/O port allowed for two-way communication between the computer and the infusion pump. With this arrangement the software program permitted an unrestricted choice of bolus dose size and lockout interval and the pump provided infusion rates of 300, 600 or 1200 $ml.h^{-1}$. The program displayed the times of all requests for bolus delivery, bolus volumes delivered and accumulated delivered volume on a video monitor and also recorded the same information on computer disk.

Pump reliability and accuracy were measured by weighing individual delivered bolus volumes of water on a precision balance (Mettler model PJ3000. Mettler Instruments, Greifensee, Switzerland).

Comparison of propofol and midazolam

Forty unpremedicated, fasted, ASA 1 day surgery patients undergoing elective surgical extraction of third molar teeth under local anaesthesia were randomly divided into two equal groups of patients who self-administered either propofol or midazolam intra-operatively.

Pre-operatively, delayed free recall was tested with single cards showing pictures of nine common objects, and mental performance was tested using the FAST index, a recently developed test [7] that requires the patient to choose as to which of two adjacent flashing lights appears to flash more often [2]. Memory cards were displayed for 30 s and free recall was tested 10 min later; FAST index testing had been interposed between the display of the card and test of recall.

All patients were instructed pre-operatively as to how to self-administer their sedation. The pump was programmed to deliver bolus volumes of 2 ml. Using the standard 10 $mg.ml^{-1}$ lipid formulation of propofol and midazolam diluted to 0.25 $mg.ml^{-1}$, the respective bolus doses for the two drugs were 20 mg and 0.5 mg, and bolus delivery time was 6 s with infusion at 1200 $ml.h^{-1}$. The lockout time, which was measured from the completion of the bolus infusion, was 1 min. The patient-controlled pump delivered the drug through a minimal volume side arm attached to the Y-piece of an infusion set, the other arm of which was fitted with a one-way valve. All patients received an intravenous infusion of one litre of crystalloid solution peri-operatively. Before the injection of the local anaesthetic (2% lignocaine with 1 : 80 000 adrenaline), patients were given 0.7 $\mu g.kg^{-1}$ of intravenous fentanyl by the anaesthetist and were then advised to self-administer one bolus dose of sedation and to repeat as required.

Intra-operatively, patients received oxygen through nasal prongs. Monitoring included electrocardiogram, pulse oximetry and automated noninvasive blood pressure measurements.

Table 1. Scoring for surgical difficulty of third molar extractions. Presurgical assessment score (1–7) is strictly applied and then (i) left unchanged, (ii) increased by 1–3 or (iii) decreased by 1–3 according to a postsurgical assessment that includes a–d (below).

A. *Presurgical assessment*	
Score	Description
1	Periodontally involved with weak bone attachment
2	Vertical unimpacted (exposed)
3	Vertical soft tissue impactation
4	Mesioangular superficial
5	Mesioangular deep or distoangular superficial
6	Distoangular deep or horizontal superficial
7	Horizontal deep
B. *Postsurgical assessment*	
a	Unfavourable root formation
b	Nerve involvement
c	Surgical access
d	Operative success including time taken

All operations were performed by the same surgeon (B.F.) who scored the procedures for surgical difficulty (Table 1). The score was allocated on the basis of the most difficult extraction. Eighteen patients in the propofol group and 16 in the midazolam group had four third molars extracted and all patients had at least the lower two third molars removed. The surgeon was blinded by a screen from the drug used for PCS and precautions were taken to blind recovery room staff and the investigator carrying out post-operative testing. The anaesthetist, who was not blinded, scored the deepest level of sedation reached by each patient on a five-point scale similar to that used by Wilson *et al.* [8] (Table 2).

Delayed free recall and FAST index accuracy were tested twice postoperatively. Different cards were used for each memory testing; the order of the cards was varied between patients. Free recall was tested for all patients 10 min after their arrival in the postoperative recovery room, without FAST index testing interposed between the picture card display and test of recall. The first postoperative FAST index testing was performed when the patient sat out of bed, which was no less than 30 min after arrival in the recovery room. Postoperative recall and FAST index were repeated when the patient was judged ready for discharge, with FAST index testing performed between picture display and recall.

All patients were contacted at home by telephone on the first postoperative day and asked how they felt during surgery (good, bad or indifferent), whether they would be prepared to repeat the procedure with the same method of sedation (yes, no or indifferent) and whether they liked the idea of self-administration of sedation (yes, no or indifferent).

Repeated measures analysis of variance with an unstructured covariance matrix [9] was used to compare delayed

Table 2. Sedation scale.

1	Fully awake
2	Drowsy
3	Eyes closed but rousable to command
4	Eyes closed but rousable to mild physical stimulation
5	Eyes closed and unrousable to mild physical stimulation

Table 3. PCS with propofol: comparison between this and a previous study [1] of pump parameters and successful and unsuccessful patient demands.

	This study	Previous study [1]
Propofol bolus dose	20 mg	0.7 $mg.kg^{-1}$
Bolus infusion rate; $ml.h^{-1}$	1200	100
Lockout period; min	1	1
Successful attempts (SD)	8.0 (4.4)	6.4 (3.6)
Unsuccessful attempts (SD)	2.8 (4.1)	34.8 (52.3)
Successful/unsuccessful ratio	2.9	0.2

recall and FAST index data for both groups. Covariates included in the analysis were patient age, sex, scored surgical difficulty, predrug value of the variable, time after completion of the operative procedure when testing occurred, total midazolam dose ($mg.kg^{-1}$) and total propofol dose ($mg.kg^{-1}$). Pearson and Spearman correlation coefficients were calculated to examine the correlation between drug dose and procedure duration and surgical difficulty respectively. The Fisher exact test was used to test data related to patient intra-operative feelings, willingness to repeat the procedure and perception of self-administration of sedation.

Results

Patient-controlled pump

The reliability and accuracy of pump delivery were such that after priming, with the pump set for 2 ml bolus volumes at 1200 $ml.h^{-1}$, mean accumulated delivered volume exceeded 46 ml calculated accumulated volume by 4.3% (SD 0.14) in three separate determinations; overall mean delivered bolus volume was 2.08 ml (SD 0.06; n = 69). The normal syringe pump alarms, for high pressure and 'end of syringe', were operational in the computer-driven mode. When compared with earlier work with patient-controlled propofol [1,2], the faster bolus infusion rate in this study permitted the use of smaller bolus doses and gave faster responses to changing patient requirements, as indicated by the improved ratio of successful to unsuccessful patient demands (Table 3).

Comparison of propofol and midazolam for PCS

Five patients in the propofol group and four in the midazolam group were male. Both groups were reasonably well matched for patient and procedure characteristics (Table 4) including surgical difficulty (Fig. 1).

One patient in the midazolam group, who pre-operatively had expressed a preference for minimal sedation, had

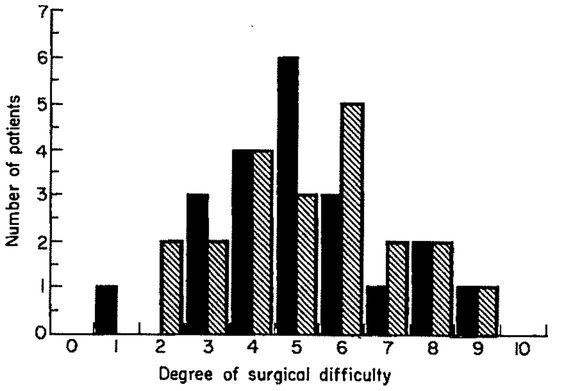

Fig. 1. Distribution of scored surgical difficulty. ■, propofol; ▨midazolam.

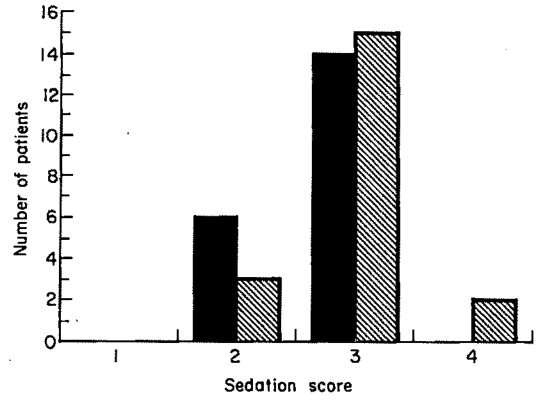

Fig. 2. Distribution of scores for deepest level of sedation. ■, propofol; ▨midazolam.

a 30 s run of frequent ventricular ectopic beats 10 min (and two self-administered doses of midazolam) after the start of the procedure. This settled spontaneously before any intervention was necessary and did not recur. There was no other cardiovascular or respiratory instability in any patient with either drug. Arterial haemoglobin oxygen saturation was maintained at 97% or greater in all patients. The distribution of sedation scores (Fig. 2) shows that, although the deepest level reached by most patients in both groups was full eyelid closure with response to verbal command, two patients in the midazolam group reached a level at which response required mild physical stimulation.

The means for successful and unsuccessful patient requests for drug delivery and drug doses for the two groups are shown in Table 5. Figure 3 details the incidence of unsuccessful demands in single lockout periods in both groups and shows that the proportion of multiple unsuccessful tries was greater in the midazolam group.

Table 4. Summary data for patients and procedures. Values are expressed as mean (SD).

	PCS propofol (n = 20)	PCS midazolam (n = 20)	p
Age; years	21.3 (2.8)	22.7 (4.8)	NS
Weight; kg	58.6 (10.9)	67.3 (14.8)	0.04
Procedure duration; min	33.6 (8.8)	35.6 (9.4)	NS
Time to sit; min	35.8 (7.5)	38.8 (11.2)	NS
Time to discharge; min	113.3 (27.1)	113.1 (30.4)	NS

NS, not significant ($p > 0.05$).

Table 5. A comparison of successful and unsuccessful demands and total drug doses (mg.kg^{-1}), for PCS propofol and PCS midazolam. Values are expressed as mean (SD).

	PCS propofol		PCS midazolam	
Successful attempts	8.0	(4.2)	14.0	(6.1)
Unsuccessful attempts	3.2	(4.7)	19.1	(21.6)
Total dose; mg.kg^{-1}	2.72	(1.37)	0.11	(0.05)

Mean number of objects recalled and mean FAST index accuracy are shown in Tables 6 and 7 respectively for purposes of illustration only. Statistical evaluation was with a repeated measures analysis of variance which showed significant differences ($p < 0.001$) between the two groups for postoperative recall and FAST index accuracy, expressed by the following, with nonsignificant covariates excluded.

1. *Recall (R = number of objects recalled)*

PCS propofol: $R_{\text{postoperative}} = 0.816\ R_{\text{pre-operative}} - 0.570$ [dose (mg.kg^{-1})]. (1)

PCS midazolam: $R_{\text{postoperative}} = 0.160\ R_{\text{pre-operative}} + 0.015$ [time (min)]. (2)

2. *Fast Index (F = percent correct choices)*

PCS propofol: $F_{\text{postoperative}} = 0.961\ F_{\text{pre-operative}}$ (3)

PCS midazolam: $F_{\text{postoperative}} = 0.884\ F_{\text{pre-operative}} + 0.029$ [time (min)]. (4)

Equations (1) and (2) indicate at 10 min after arrival in recovery, in the propofol dose range used, recall was less impaired in the propofol group than in the midazolam group. Impairment of recall was dose dependent in the propofol group but the more severely affected midazolam group showed no statistically significant dose dependence. During the recovery period there was some statistically significant improvement in recall with time for the midazolam group but not for the propofol group.

Equations (3) and (4) show postoperative FAST index accuracy was more impaired in the midazolam group compared to the propofol group over the postoperative interval of testing. There was no statistically significant change in postoperative scores with time in the propofol group, but the midazolam group showed a small but statistically significant tendency to improve with time over the postoperative period tested. There was no statistically significant drug dose-dependent effect for FAST index accuracy in either the propofol or midazolam group.

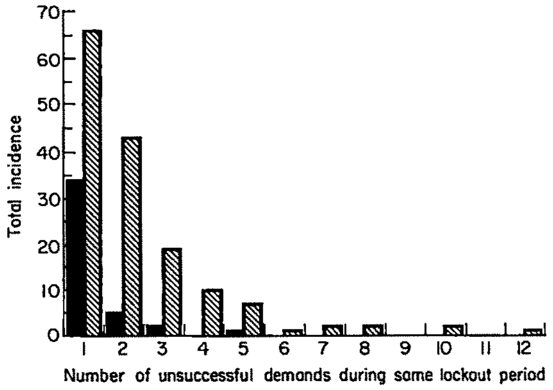

Fig. 3. Total incidence of single and multiple unsuccessful patient demands during the same lockout period, in each group. ■, propofol; ▨midazolam.

The total dose of midazolam self-administered in each procedure (mg.kg^{-1}) showed some correlation with duration of procedure ($r = 0.50$; $p = 0.02$) but no significant correlation with surgical difficulty ($r_s = 0.21$; $p = 0.35$). There was no significant correlation between total propofol dose (mg.kg^{-1}) and either procedure duration ($r = 0.25$; $p = 0.30$) or surgical difficulty ($r_s = 0.26$; $p = 0.25$).

There was no significant difference between groups for patient satisfaction elicited on the day after surgery. Nineteen of the propofol group described their intra-operative feelings as 'good' and one was 'indifferent ' compared with 18 'good' and two 'indifferent' in the midazolam group. All patients in the propofol group and 19 in the midazolam group said they would, if required, repeat the procedure and technique and everyone in the propofol group and 19 in the midazolam group liked the idea of self-administration of sedation.

Discussion

The pump assembled for this study performed to a satisfactory standard and demonstrated the advantage of rapid bolus infusion for PCS. The successful to unsuccessful

Table 6. Mean number of objects recalled pre-operatively, 10 min after arrival in recovery (postoperative 1) and at time when ready for discharge (postoperative 2) for both groups. Values are expressed as mean (SD).

	Pre-operative	Postoperative 1	Postoperative 2
Propofol	7.2 (1.3)	3.8 (2.5)	4.7 (2.0)
Midazolam	7.1 (1.3)	0.9 (2.3)	2.9 (2.6)

Table 7. Mean FAST index accuracy (percent correct choices) pre-operatively, at time of first sitting in recovery (Postoperative 1) and at time when ready for discharge (Postoperative 2) for both groups. Values are expressed as mean (SD).

	Pre-operative	Postoperative 1	Postoperative 2
Propofol	87.4 (6.7)	85.0 (9.8)	82.8 (10.2)
Midazolam	88.8 (6.5)	80.3 (10.2)	81.7 (10.2)

demand ratios were improved when compared with previous work using propofol for PCS [1,2] and the faster infusion rate permitted the use of a smaller bolus dose.

The less favourable demand ratio for midazolam is likely to be related to its slower onset of effect. However, the persistence of many unsuccessful demands throughout many of the operative procedures when midazolam was used, in spite of patients apparently being sedated to levels similar to or deeper than those in the propofol patients, raises the possibility that differences between the drugs for dose-dependent anxiolysis, other mood alteration or analgesia may also be involved. Although the midazolam demand ratio might be improved with midazolam bolus doses exceeding 0.5 mg, this may also increase the risk of oversedation. In our experience, with patients and bolus doses similar to those used in this study, the time from patient demand to when they first report feeling the effect of the drug can easily and reliably be measured for propofol (35–40 s) but not for midazolam. This is because of a less clearly defined onset of effect. Other evidence of variable delayed onset of effect with midazolam includes work with the processed electroencephalogram (EEG), which has been recently used to measure central nervous system (CNS) drug effect. This shows that maximal EEG changes can take 5–10 min to develop after sedative doses of intravenous midazolam [10]. There is, therefore, a possibility of oversedation from 'dose stacking' with midazolam, so that the full effect of closely spaced doses may not be observed until some time after the last dose[11].

Delayed free recall is a sensitive measure of episodic, declarative memory, which is known to be significantly affected by the benzodiazepines [12]. Since recall at the first pre-operative testing after midazolam was profoundly affected (17 patients could not remember any of the nine pictures shown to them) it is not surprising that there was a lack of dose-dependent effect on recall over the midazolam dose range used. Postoperative recall of patients in the propofol group was less affected and was dose dependent. In the propofol group, the lack of significant improvement in recall with time in recovery may have been related to the fact that the first postoperative score was artificially elevated, since on this occasion the FAST index testing was not interposed between picture display and test of recall. However, such differences in time-dependent and dose-dependent behaviour between the drugs may also be affected by more rapid redistribution of propofol. so that, by the time of postoperative testing, CNS levels of propofol are changing more slowly than those of midazolam.

Although patients occasionally needed to be prompted, mostly they did remember how and why they had to press the demand button, therefore nondeclarative memory for tasks learned pre-operatively appeared to remain largely intact during sedation with both propofol and midazolam. However, postoperatively, in the case of both drugs, patients did not remember pressing the demand button more than about three times.

Postoperative mental performance, which was more impaired in the midazolam group, showed small but significant improvement with time in recovery in that group, without significant midazolam dose-dependent impairment. In earlier work [2], anaesthetist-administered midazolam produced dose-dependent impairment of mental function with no significant improvement with time over similar recovery intervals. These differences, and the modest correlation between midazolam dose and procedure duration in this study, which was not seen in earlier work with anaesthetist-administered midazolam [2], suggests that PCS allows patients to titrate the dose according to their own perceived needs. Thus fewer patients were oversedated, permitting more rapid recovery from drug effect.

The lack of significant correlation between propofol dose and either procedure duration or surgical difficulty illustrates the variability that occurs in patient sedation requirements for procedures of similar difficulty and duration. The lack of correlation in this study, compared to the modest but significant correlation seen between these variables in earlier work with PCS propofol [2], may be related to the smaller range of total propofol doses in this study.

Patient satisfaction for the patient-controlled technique was high in both groups. PCS, in addition to its ability to provide effective and safe intra-operative sedation that matches individual patient requirements, can also provide information on how patients feel intra-operatively, to complement what patients remember after their procedure. The total peri-operative experience of patients receiving sedation may depend on drug pharmacokinetics and the pharmacodynamic properties of separate components of sedation, including hypnosis, amnesia, anxiolysis and other affective properties, in addition to the mode of drug delivery. In this respect, PCS also may contribute toward the need for '. . . objective quantifiable pharmacodynamic measures . . . (of) CNS effect' [11], for drugs used for sedation.

This study indicates that propfol is more suitable than midazolam for PCS because of its more rapid response to fluctuating patient requirements, as shown by a more favourable ratio of successful to unsuccessful demands, without oversedation. In addition, recovery of memory and mental performance, which is of particular importance for day surgery, was faster in patients who received propofol. Propofol also appeared to have a more beneficial effect on patient mood.

The anaesthetists and surgeon involved in this study found PCS to be a safe technique which provided good intra-operative conditions and a high level of patient satisfaction.

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Propofol and hypothermic cardiopulmonary bypass

Vasodilation and enhanced metabolic protection?

G. J. A. LAYCOCK AND R. P. ALSTON

Summary

The effects of propofol during low flow (1.6 $l.min^{-1}.m^{-2}$*) hypothermic (27–29° C) cardiopulmonary bypass on systemic haemodynamic and metabolic variables were studied in 20 patients in a parallel group comparison. Patients in the control group underwent two consecutive control periods, whereas those in the propofol group underwent a control period followed by a 'propofol' period during which they received an intravenous bolus of propofol 5* $mg.kg^{-1}$ *followed by an infusion at a rate of 20* $mg.kg^{-1}.h^{-1}$*. Haemodynamic and metabolic variables were measured at the end of each period. The propofol group showed a significant reduction in both systemic vascular resistance (*$p < 0.001$*) and systemic oxygen uptake (*$p < 0.05$*). There was a small but significant fall in lactate in the control group (*$p < 0.02$*); however, there was no significant change in the propofol group. These findings could indicate impaired tissue perfusion, although they more likely indicate systemic metabolic depression with washout of lactate from previously hypoperfused tissues.*

Key words

Anaesthetics, intravenous; propofol.
Cardiopulmonary bypass.
Oxygen consumption.

In the United Kingdom a wide variety of techniques are utilised to maintain anaesthesia during hypothermic cardiopulmonary bypass (CPB). Most anaesthetists use a balanced technique consisting of various combinations of narcotics, benzodiazepines, volatile agents and muscle relaxants [1]. The primary aims of anaesthesia during CPB are to provide analgesia, hypnosis and to prevent reflex movements. However, anaesthetic agents such as propofol may also have beneficial effects on systemic metabolism. Propofol has two possible mechanisms of improving systemic metabolism during CPB. Direct metabolic depression [2,3] may, like hypothermia [4,5], have a systemic protective action by allowing tissue hypoperfusion to be tolerated for longer before the occurrence of structural or functional damage. This would be a valuable action, as systemic oxygen uptake ($\dot{V}O_2$) is less than maximal during low-flow hypothermic CPB [6].

Alternatively, propofol has a vasodilatory action [7] which may reduce the relatively elevated peripheral vascular resistance that exists during low-flow hypothermic CPB [8], thus enhancing perfusion in areas of ischaemia or hypoperfusion. This study was undertaken to examine the effects of propofol on systemic haemodynamic and metabolic variables during low-flow hypothermic CPB.

Methods

The study was approved by the local hospital ethics committee. Patients who were scheduled for elective coronary artery surgery and had given informed consent were admitted to the study. Exclusion criteria from the study included patients with carotid artery and cerebrovascular disease, severe hepatic disease, renal failure, poor left ventricular function and diabetes mellitus.

Patients were premedicated by the oral route with lorazempan 3–4 mg on the evening before surgery and temazepam 30–40 mg approximately 1 h before surgery. All patients received their routine anti-anginal medication on the morning of surgery. Anaesthesia was induced intravenously with fentanyl 5 $\mu g.kg^{-1}$ and a dose of midazolam sufficient to obtund the eyelash reflex. Neuromuscular blockade was obtained with an intravenous bolus of atracurium 0.6 $mg.kg^{-1}$ and the patient's trachea was intubated. Supplemental atracurium was given as necessary. Normocapnia was maintained by ventilation of the lungs with nitrous oxide and oxygen (50:50) before cardiopulmonary bypass, and with 100% oxygen after the start of CPB. Anaesthesia was maintained throughout surgery with an intravenous fentanyl infusion (0.1 $\mu g.kg^{-1}.min^{-1}$). This

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was supplemented with isoflurane 0.5–2% as required, before and after CPB. No vasoactive drugs were given before CPB.

A standard CPB technique was used in all patients. Before aortic cannulation, patients were anticoagulated with heparin 300 $IU.kg^{-1}$. The bypass circuit consisted of a bubble oxygenator (Bentley BOS 10 plus) and a roller pump (Stockert Instruments) which was primed with compound sodium lactate solution 2 l, 20% mannitol 100 ml, potassium chloride 15 mmol and heparin 8000 units. Pump flows were 2.4 $l.min^{-1}.m^{-2}$ during cooling and rewarming. After induction of stable hypothermia (arterial and nasopharyngeal temperature 27–29° C), the flow was reduced to 1.6 $l.min^{-1}.m^{-2}$. Nonpulsatile perfusion and alpha-stat acid-base management were employed. Hypotension during CPB was defined as a mean arterial pressure (MAP) less than 30 mmHg and was treated with intravenous boluses of methoxamine 2.0 mg to maintain it at this level. Hypertension was defined as a MAP greater than 85 mmHg and was corrected to this level with intravenous boluses of phentolamine 2.5 mg. No fluid was added to the pump or given by the anaesthetist during the study periods.

Patients were randomly allocated into two equal groups. After establishing hypothermia, a 10-min period was allowed in both groups for stabilisation (period 1). In the control group, this was followed by a second 10-min control period (period 2) during which the patients received no propofol. In contrast, patients in the propofol group were given a bolus of propofol 5 $mg.kg^{-1}$ at the beginning of period 2, followed by an infusion of propofol at 20 $mg.kg^{-1}.h^{-1}$. Propofol was infused directly into the bubble oxygenator.

Systemic arterial and central venous pressures were continuously monitored thoughout the procedure; details of the methods have been presented previously [7]. At the end of each study period recordings were made of mean arterial pressure (MAP), central venous pressure (CVP), reservoir level, pump flow, nasopharyngeal and arterial blood temperature. Systemic vascular resistance (SVR) was calculated from MAP and pump flow rate (Appendix I). The CVP was treated as zero, as single isolated measurements may be erroneous during CPB. At the end of each 10-min study period samples from the arterial and venous lines of the CPB circuit were aspirated into glass syringes. Arterial blood was taken from the arterial filter after discarding dead space blood and venous blood was taken from a sampling port situated in the venous line immediately before its entry into the oxygenator.

Table 1. Demographic data and duration of cardiopulmonary bypass. Values are expressed as mean (SD).

	Control group	Propofol group
Sex M/F; *n*	7/3	10/0
Age; years	60 (7.8)	56 (5.5)
Weight; kg	71 (8.7)	79 (7.2)*
Height; m	165 (8.0)	168 (19.0)
Surface area; m^2	1.78 (0.15)	1.88 (0.2)
Cardiopulmonary bypass; min	79 (21)	80 (22)
Aortic cross-clamp; min	45 (19)	45 (13)

*$p < 0.05$.

Blood samples were placed in ice and analysed immediately for Po_2, Pco_2 and pH (measured at 37° C) using a Corning 178 blood gas analyser, for oxygen saturation and haemoglobin concentration using an IL 282 Co-oximeter, and packed cell volume (PCV). All analyses were performed in duplicate by technicians blind to the study and the mean of the two measurements used. Further samples of venous blood were placed in fluoride/oxalate bottles and after separation, the plasma was frozen for later determination of lactate levels. In the propofol group heparinised venous samples were taken to measure propofol concentration by high performance liquid chromatography. Arterial and venous oxygen content were calculated using a standard formula (Appendix II). Systemic oxygen delivery was calculated as the product of pump flow rate and the arterial oxygen content. Systemic oxygen uptake ($\dot{V}O_2$) was calculated as the product of the pump flow rate and the arterio-venous oxygen content difference.

Data were analysed using Student's *t*-test for parametric data and Mann–Whitney *U* and Wilcoxon's tests for nonparametric data as appropriate. A significance level of 5% was used ($p < 0.05$).

Results

A total of 20 patients were recruited to the study. Patients in the propofol group weighed significantly more than those in the control group (see Table 1). However, there was no significant difference in surface area between the groups nor were there any other significant differences in demographic details or duration of CPB. Good control of arterial and nasopharyngeal temperatures was maintained in both groups and there were no significant differences in pH, or arterial carbon dioxide tension between groups (see Table 2). The propofol group had a mean venous blood propofol concentration at the end of period 2 of 9.2 (SD 2.1) $\mu g.ml^{-1}$.

In the control group, MAP and SVR increased by an average 14% ($p < 0.01$) between period 1 and 2 (see Table 3 and Fig. 1). In the propofol group, they both decreased by an average of 40% ($p < 0.001$). The mean reservoir levels fell in the control group by 18% (NS) and in the

Table 2. Changes in arterial (Ta) and nasopharyngeal (Tnp) temperatures, arterial pH (pHa) and arterial carbon dioxide tension ($Paco_2$) in the control and propofol groups. Values are expressed as mean (SD).

	Control group		Propofol group	
	Period 1	Period 2	Period 1	Period 2
Ta; °C	27.9 (0.4)	27.9 (0.29)	27.3 (0.7)	27.7 (0.38)
Tnp; °C	28.2 (0.36)	28.2 (0.2)	28.1 (0.39)	28.0 (0.13)
pHa	7.36 (0.03)	7.35 (0.03)	7.35 (0.05)	7.34 (0.03)
$Paco_2$; mmHg	44 (3.3)	45 (3.0)	46 (5.5)	47 (4.6)

Table 3. Changes in mean arterial pressure (MAP), systemic vascular resistance (SVR) and pump reservoir level in the control and propofol groups. Values are expressed as mean (SD).

	Control group		Propofol group	
	Period 1	Period 2	Period 1	Period 2
MAP; mmHg	51 (10.9)	58 (13.8)**	58 (14)	35 (3.2)***
SVR; dyn.s.cm^{-5}	1412 (265)	1609 (366)**	1493 (364)	898 (112)***
Reservoir; ml	1250 (400)	1020 (424)	1490 (448)	955 (38)*

*$p < 0.05$ **$p < 0.01$ ***$p < 0.001$

propofol group by 36% ($p < 0.05$). During CPB, methoxamine was given to correct hypotension in two patients in the control group and three in the propofol group. Phentolamine was given to one patient in the control group for hypertension.

There were no significant changes in PCV or oxygen delivery in either group (see Table 4 and Fig. 2). In the control group, there was no significant change in S$\dot{V}O_2$ or $\dot{V}O_2$ between period 1 and 2. In contrast, the propofol group showed a 3% mean rise in S$\dot{V}O_2$ ($p < 0.02$) and 14% mean fall in $\dot{V}O_2$ ($p < 0.05$). Blood lactate concentrations fell on average by 7% ($p < 0.02$) in the control group but showed no significant change in the propofol group.

Discussion

The outstanding findings of this study are that not only did propofol produce a marked decrease in SVR, but it also

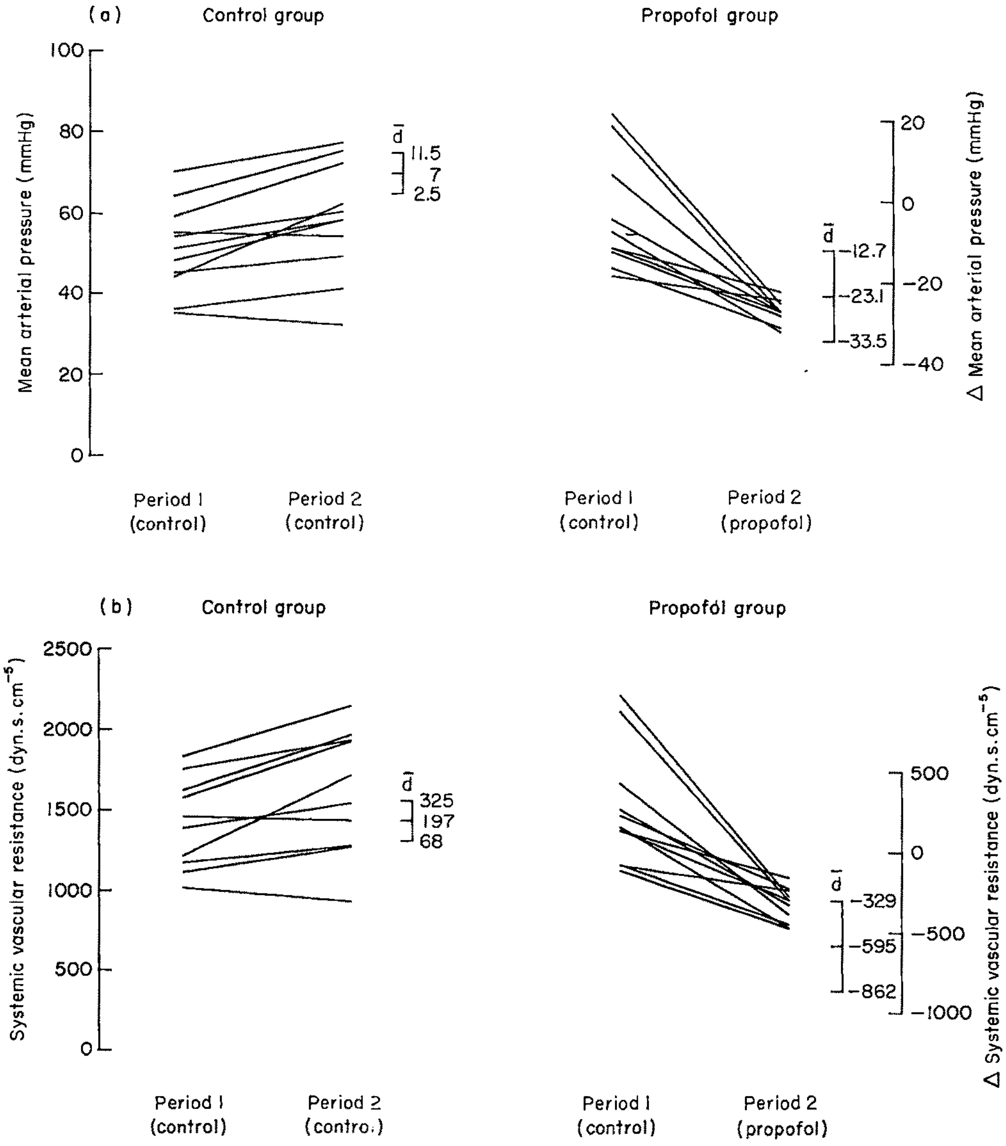

Fig. 1. Individual changes in MAP (a) and SVR (b). d̄ indicates change in mean of groups from period 1 to period 2, with 95% confidence limits of mean change.

Table 4. Changes in packed cell volume (PCV), mixed venous haemoglobin oxygen saturation (SVO_2), oxygen delivery ($\dot{D}O_2$), oxygen uptake ($\dot{V}O_2$) and blood lactate in the control and propofol groups. Values are expressed as mean (SD).

	Control group		Propofol group	
	Period 1	Period 2	Period 1	Period 2
PCV; %	23 (3.3)	24 (2.9)	25 (1.1)	26 (2.9)
Oxygen delivery; $ml.min^{-1}.m^{-2}$	172 (19)	175 (21)	182 (17)	186 (14)
SVO_2; %	75.2 (3.8)	75.3 (4.5)	75.5 (4.4)	77.6 (3.1)**
$\dot{V}O_2$; $ml.min^{-1}.m^{-2}$	45 (6.3)	47 (8.0)	47 (5.1)	40 (6.6)*
Lactate; $mmol.l^{-1}$	2.73 (0.5)	2.54 (0.6)**	2.58 (0.4)	2.65 (0.4)

*$p < 0.05$ **$p < 0.02$.

caused a decrease in $\dot{V}O_2$. While vasodilation is known to occur with other anaesthetics such as fentanyl, halothane and to a greater extent isoflurane during CPB [9, 10], no previous anaesthetic has been shown to affect $\dot{V}O_2$ during hypothermic CPB.

Anaesthetic agents are well known to suppress metabolic rate at normothermia. Reductions in $\dot{V}O_2$ at normothermia have been demonstrated with halothane [11], isoflurane [12], thiopentone and fentanyl [13], and during normothermic CPB with muscle relaxants (tubocurare or decamethonium) when compared to cyclopropane [14]. However, during hypothermic CPB, the metabolic effects

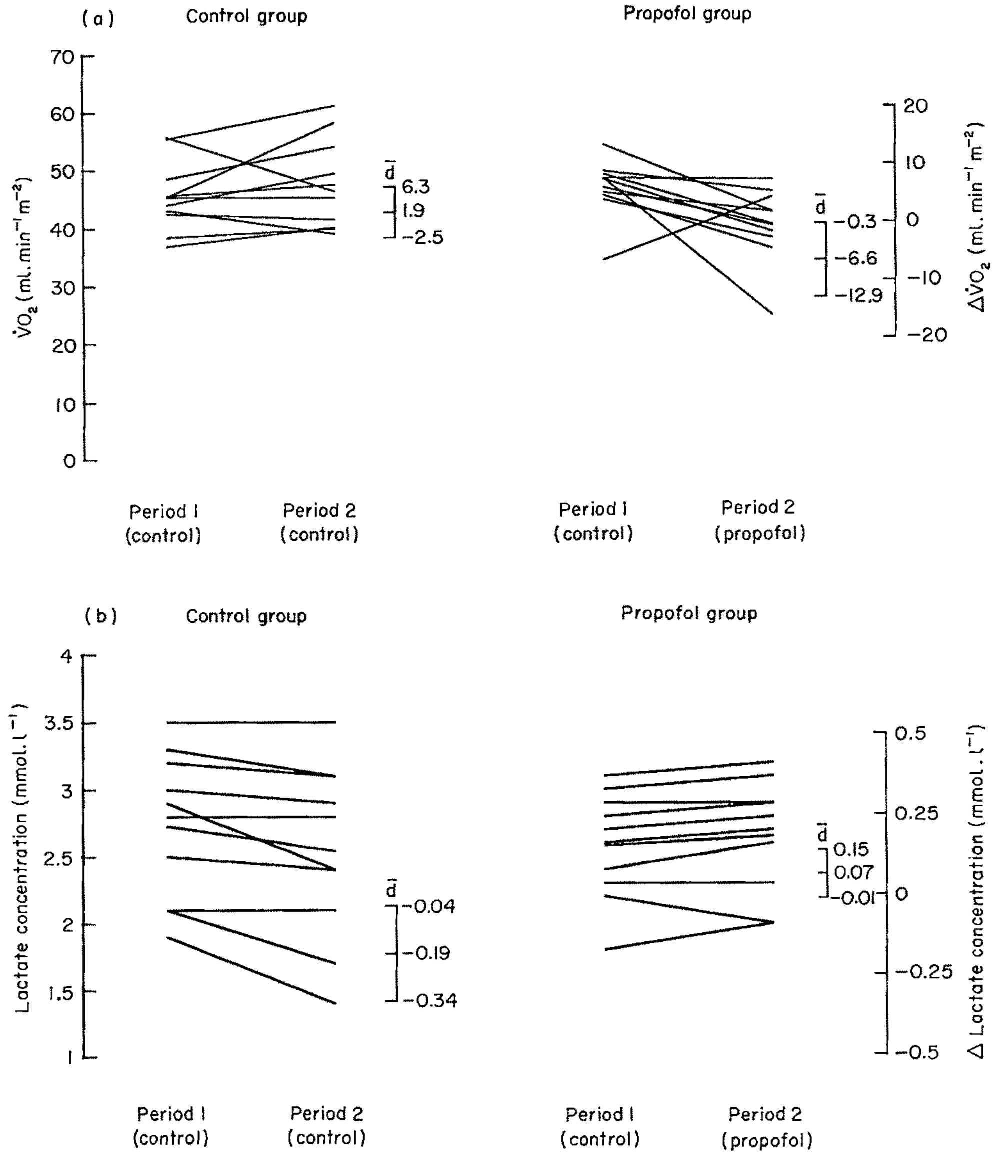

Fig. 2. Individual changes in systemic oxygen uptake (a) and blood lactate (b). $\bar{d}$ indicates change in mean of groups from period 1 to period 2, with 95% confidence limits of mean change.

of anaesthetics on $\dot{V}O_2$ are generally assumed to be insignificant, when compared to the known effects of hypothermia [5].

Previous metabolic studies with anaesthetic agents during hypothermic CPB have concentrated on reductions in cerebral metabolic rate ($CMRO_2$) and their possible role in cerebral protection. Both thiopentone and isoflurane have been shown to reduce $CMRO_2$ significantly during hypothermic CPB [15]. The effect of thiopentone on $\dot{V}O_2$ during hypothermic CPB is unknown; however, thiopentone is the only anaesthetic agent so far shown to improve outcome after CPB although this was at normothermia [16]. A recent study in our hospital showed no apparent effect of isoflurane on $\dot{V}O_2$ during hypothermic CPB [17]. Although brain survival is of primary importance, damage relating to CPB is multi-organ in nature [18], hence the need to study the effects of anaesthesia on $\dot{V}O_2$. While a reduction in $CMRO_2$ will contribute to a reduction in $\dot{V}O_2$, anaesthetic-induced metabolic depression occurs in many other organs, which is potentially beneficial during CPB [12].

Propofol has been shown to reduce $CMRO_2$ at normothermia in humans by 18–36% [2,3], but the effects of propofol on $CMRO_2$ during hypothermic CPB are unknown. Our study has shown a significant reduction in $\dot{V}O_2$ during hypothermic CPB; however, we can make no comment as to the cerebral effects of propofol. If generalised metabolic depression is an important mechanism for organ protection then propofol may prove to be a more appropriate agent to use during CPB than thiopentone, due to its rapid elimination.

The choice of drug dosage in this study resulted from the desire to obtain maximal systemic metabolic depression using propofol supplemental to hypothermia and a fentanyl-based anaesthetic. With thiopentone, the maximum reduction in $CMRO_2$ is achieved when the EEG is isoelectric [19] and EEG suppression was used to demonstrate the reduction in $CMRO_2$ during hypothermic CPB [15]. This contrasts with the effect of hypothermia alone, where a progressive fall in body temperature leads to continuing reductions in both $CMRO_2$ and $\dot{V}O_2$ [4,5]. A study in our department suggested that EEG suppression occurs with propofol levels around 6–10 $\mu g.ml^{-1}$ at normothermia (unpublished data). We therefore aimed to achieve this level of propofol during this study. Subsequent work in our unit has shown that a blood propofol level of 3 $\mu g.ml^{-1}$ would be sufficient to produce EEG suppression reliably at 28° C in most adults [20].

This study has confirmed the findings of Boer and coworkers that propofol is a vasodilator during hypothermic CPB [7]. Despite this vasodilation, and without any significant change in oxygen delivery, patients given propofol showed an 18% reduction in $\dot{V}O_2$ relative to the control group. There are two likely explanations for the decrease in $\dot{V}O_2$. Propofol may have produced direct metabolic depression, or alternatively, its vasodilatory action may have produced maldistribution of tissue blood flow. Propofol caused a marked reduction in MAP and SVR which would support the second hypothesis. However, Evans and colleagues produced similar changes in haemodynamic variables with sodium nitroprusside during stable hypothermic CPB and found no effect on $\dot{V}O_2$ [21]. Isoflurane also significantly reduces the SVR during hypothermic CPB with no apparent effect on $\dot{V}O_2$ [10,17]. This would suggest that direct metabolic depression accounts for the reduction in $\dot{V}O_2$ in the propofol group, although consideration of the changes in lactate concentration makes this conclusion less certain.

Blood lactate concentration usually falls by a small amount during the course of CPB, as seen in our control group, either as a result of redistribution or metabolism of lactate present in the pump-priming solution [6]. There was a very small rise (not statistically significant) in lactate concentration in the propofol group, although the absolute value of 2.65 $mmol.l^{-1}$ was well within the acceptable range [5]. Possible reasons for this small increase are reduced lactate metabolism with resultant accumulation, underperfusion of the tissues with an increase in anaerobic metabolism or sudden vasodilatation opening up previously constricted vascular beds and washing out of stored lactate. We consider the latter reason most likely because the propofol was given after a period of hypothermic CPB, during which widespread vasoconstriction is known to occur. Subsequent work giving propofol by continuous infusion throughout bypass to maintain EEG suppression in children, has shown falling lactates in both control and propofol groups during bypass [22]. It is interesting that isoflurane, although acting as a vasodilator during hypothermic CPB, had no effect on $\dot{V}O_2$ or blood lactate levels [17].

Propofol is now being used to maintain anaesthesia throughout cardiac surgery [23]. While the ability of propofol to reduce the cardiac index and SVR before and after CPB may limit its use during these periods [24], this study indicates it may have a useful role in organ protection during CPB. Reves and colleagues have recently suggested that increased depth of anaesthesia may protect against damage associated with CPB [9]. The mechanisms for this protection are likely to include metabolic depression. If propofol does reduce $\dot{V}O_2$ by metabolic depression and potentiate the protective effect of hypothermia, it may prove a valuable aid in reducing the morbidity following surgery involving CPB.

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Appendix I

$$SVR = \frac{MAP}{Q} \times 80$$

where: SVR = systemic vascular resistance ($dyn.s.cm^{-5}$)

MAP = mean arterial pressure (mmHg)

Q = pump flow ($l.min^{-1}$)

Appendix II

$$CO_2 = 1.34 \times Hb \times Sao_2 + (Pao_2 \times 0.003)$$

where: CO_2 = oxygen content ($ml.dl^{-1}$)

Hb = haemoglobin concentration ($g.dl^{-1}$)

Sao_2 = haemoglobin oxygen saturation (%)

Pao_2 = blood oxygen partial pressure (mmHg)

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Thoracic epidural infusion for postoperative pain relief following abdominal aortic surgery: bupivacaine, fentanyl or a mixture of both?

K. A. GEORGE, A. M. CHISAKUTA, J. A. S. GAMBLE AND G. A. BROWNE

Summary

Thirty patients who had undergone elective abdominal aortic surgery were studied in a prospective, randomised double-blind comparison of thoracic epidural 0.2% bupivacaine alone, thoracic epidural fentanyl alone and thoracic epidural 0.2% bupivacaine combined with fentanyl. Pain relief, pulmonary function, cardiovascular stability and side effects were assessed. Pain relief was excellent in the combined bupivacaine–fentanyl series, being significantly better than the other groups ($p < 0.05$) during the entire study period and was not accompanied by hypotension. Forced expiratory parameters were reduced in all groups throughout the study to 50–60% of the pre-operative values, but there were no significant differences between groups. The incidence of side effects attributable to either epidural bupivacaine or fentanyl was low. This study supports the increasing use of epidural infusion analgesia for postoperative pain management after abdominal surgery.

Key words

Anaesthetic technique, regional; epidural.
Analgesics; fentanyl.
Anaesthetics, local; bupivacaine.

Bupivacaine may be considered the drug of choice for epidural analgesia [1] as it has a wide margin of safety [2], and gives the least motor block for any given degree of sensory block [3]. Despite these qualities, bupivacaine is associated with side effects which include motor block and sympathetic block with consequent hypotension and haemodynamic instability [2]. However, some researchers have reported less hypotension if a continuous infused dosage is used [4], while others have reported significant decreases in blood pressure as well as motor block, numbness, nausea and urinary retention with this technique [2,5]. Moreover, maintenance of the degree of pain relief is often difficult due to regression of analgesia and tachyphylaxis [6,7].

To overcome these problems, the use of epidural infusion of opioids has been examined [8–13]. However, the use of epidural morphine has been limited clinically by the frequent occurrence of pruritus, nausea, urinary retention [8] and severe respiratory depression. Recently we examined the quality of pain relief and effect on lung function, when thoracic epidural fentanyl alone or combined with 0.2% bupivacaine was used following thoracotomy. Continuous thoracic epidural infusion of 0.2% bupivacaine and fentanyl provided greater pain relief with better oxygenation, compared to fentanyl alone during the first 24 h [14].

The aim of the present study was to compare and assess the quality of analgesia, the effect on lung function, and the side effects following the use of continuous thoracic epidural infusion of: fentanyl (30–50 $\mu g.h^{-1}$), 0.2% bupivacaine (6–10 $mg.h^{-1}$) and a combination of fentanyl (30–50 $\mu g.h^{-1}$) with 0.2% bupivacaine (6–10 $mg.h^{-1}$) in patients who had undergone elective abdominal aortic surgery.

Methods

The study was carried out after approval by the local Medical Ethics Committee and with informed patient consent. Thirty-six adult patients, ASA 2–3, undergoing elective abdominal aortic surgery were studied. One hour before surgery, the patients were premedicated with temazepam 10 mg orally. In the operating theatre, after placement of peripheral venous, central venous and radial artery

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cannulae, an epidural catheter was inserted through either the T_{7-8} or T_{8-9} interspinous space with 3 cm of catheter being left in the epidural space. All patients then received 8 ml of 0.5% bupivacaine through the epidural catheter. Fifteen minutes later the upper and lower levels of sensory block were determined using ethyl chloride.

Anaesthesia was then induced with intravenous fentanyl 50–100 μg followed by sufficient thiopentone to obtund the eyelash reflex. Muscle relaxation was achieved with atracurium, and anaesthesia was maintained with nitrous oxide, oxygen and isoflurane. No other opioid was administered during surgery. An infusion of dopamine at a rate of 3 μg.kg^{-1}.min^{-1} was commenced and continued for 24 h following surgery. All patients received heparin 5000 IU intravenously before aortic clamping. After the operation, residual muscle relaxation was reversed with a mixture of neostigmine and glycopyrronium and patients' tracheas were extubated in the operating theatre. Patients were then taken to the intensive care unit (ICU) where they were allocated, in a random fashion, to receive an epidural infusion of either bupivacaine 0.2%, fentanyl 10 μg.ml^{-1}, or bupivacaine 0.2% with fentanyl 10 μg.ml^{-1}. These coded test solutions were prepared in the hospital pharmacy, and were not disclosed to the patient or the investigators.

Each patient received 5 ml of the test solution epidurally and subsequently a continuous epidural infusion at 5 ml.h^{-1}. The infusion was adjusted according to the quality of analgesia; if the analgesia was complete the infusion was reduced in 0.5 ml stages to 3 ml.h^{-1}, if more analgesia was required later, the infusion was increased to a maximum of 5 ml.h^{-1}. Further analgesia, if required, was provided with morphine using a patient-controlled analgesia (PCA) system, set to deliver boluses of 2 mg up to a maximum of 10 mg.h^{-1}. Instruction in the use of the PCA system was given to each patient on the day before surgery. Patients remained in the ICU for a minimum period of 24 h after the operation. All patients received 40% humidified oxygen by mask.

Measurements

Pre-operatively, following instruction in the techniques involved, pulmonary function was assessed by measurements of forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), and peak expiratory flow (PEF) using a pneumotachograph-based vitalograph (Alpha Vitalograph Ltd). Arterial pH and blood gas analysis was also performed. Measurements were made with the patient semirecumbent in bed, the position in which the patient would be nursed postoperatively. At 6, 12, 18 and 24 h after the operation, repeated assessments of pain, sedation, FVC, FEV_1, PEF and arterial blood gases were made. Pain relief was assessed by the use of serial 100 mm visual analogue scores (VAS) with anchor points labelled as 'no pain' and 'the worst possible pain'. The total volume of test solution infused epidurally over the 24 h period of the study was recorded, as well as the total dose of morphine used by each patient from the PCA system over the same study period.

Postoperative sedation was scored using a previously determined scale [15]. Patients were questioned to determine the incidence of itch, nausea, vomiting, numbness or limb weakness. All patients had urinary catheters inserted following induction of anaesthesia and therefore the effect of epidural infusion on bladder function could not be assessed.

Comparisons were made between groups using ANOVA, Kruskal–Wallis and Mann–Whitney *U* tests. Comparisons of the extent of analgesia within groups were made using the Mann–Whitney *U* tests. Adverse side effects were compared using the Fisher exact test. Statistical significance was taken as $p < 0.05$.

Results

Thirty-six patients were entered into the study but six patients were withdrawn for reasons unrelated to the investigation. Of the remaining 30 patients, 10 received bupivacaine, 10 fentanyl and the remaining 10 received a bupivacaine–fentanyl mixture. The three groups were comparable in age, weight, height, sex, ASA classification, duration of operation and for other variables recorded before the operation (Table 1).

The patients in the bupivacaine and fentanyl alone groups received more intravenous morphine (0.6 mg.kg^{-1}.24 h^{-1} and 0.2 mg.kg^{-1}.24 h^{-1} respectively) than the mixture group (0.06 mg.kg^{-1}.24 h^{-1}) from the PCA system ($p < 0.05$), in addition to the test solution given epidurally. The total volume of the test solution administered was a mean of 131 ml (range 112.5–140), 125 ml (range 118–133) and 111 ml (range 66.5–125), in the bupivacaine, fentanyl and mixture groups respectively. The bupivacaine and fentanyl alone groups thus received more test solution than the mixture group ($p < 0.05$), but there was no significant difference between the former groups.

Table 1. Demographic characteristics and pre-operative variables; mean (ranges).

	Bupivacaine (n = 10)	Fentanyl (n = 10)	Mixture (n = 10)
Age; years	66.9 (58–85)	62.3 (51–71)	63.5 (43–75)
Weight; kg	66.7 (53–88)	65.4 (45–80)	68.8 (45–90)
Height; cm	165 (156–176)	167 (157–179)	169 (156–183)
M : F	6 : 4	4 : 6	8 : 2
Duration of surgery; min	125 (90–180)	138 (90–225)	133 (70–180)
SAP; mmHg	154 (130–180)	150 (128–180)	144 (110–180)
HR; beat.min^{-1}	72 (65–82)	78 (60–98)	76 (68–82)
RR; breath.min^{-1}	20 (18–22)	20 (18–24)	20 (16–21)
PEF; l.min^{-1}	395 (162–504)	380 (184–500)	396 (222–612)
FEV_1; l	1.94 (1.06–3.29)	1.82 (0.89–2.86)	2.41 (1.50–3.75)
FVC; l	2.45 (1.92–4.05)	2.76 (1.33–3.94)	3.14 (2.24–4.28)

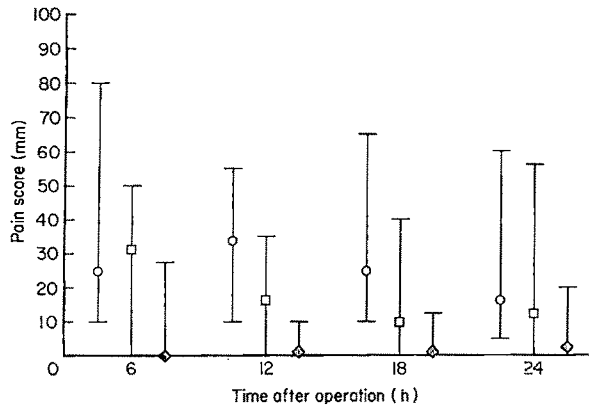

Fig. 1. Median (range) pain scores during the 24 h after operation. ○, bupivacaine; □, fentanyl; ◇, mixture.

Median pain scores were greater in the bupivacaine and fentanyl alone groups ($p < 0.05$), compared with the mixture group whose score remained less than 5 mm in the 24 h study period (Figs 1 and 2). Analgesic failure (defined as VAS for pain > 30 mm) at some point during the study period, occurred in seven and six of the bupivacaine and fentanyl alone patients respectively. No patients in the mixture series had analgesic failure ($p < 0.05$). In fact in this group nine patients had maximum pain scores of less than 15 mm, while the remaining patient had a maximum pain score of 28 mm.

Heart rate (HR), systolic arterial blood pressure (SAP) and respiratory rate (RR) all showed a reduction from their pre-operative values of about 5–10% (Fig. 3) during the study period. Hypotension (defined as a drop of over 20% from the pre-operative value or systolic arterial blood pressure of less than 100 mmHg) did not occur during this period. At no time during the study was there any respiratory depression (defined as $Pa\text{CO}_2$ greater than 6.5 kPa or respiratory rate < 10 breath.min^{-1}).

Table 2. Adverse side effects.

	Bupivacaine (n = 10)	Fentanyl (n = 10)	Mixture (n = 10)
Sedation			
Grade 1	8	6	7
2	2	3	3
3	0	1	0
4	0	0	0
5	0	0	0
Pruritus	0	3	2
Emetic symptoms	3	5	2
Numbness	4	2	0
Limb weakness	1	0	1

FVC, FEV_1 and PEF were all reduced to 50–60% of their pre-operative values throughout the study period in all the three treatment groups. There was no significant difference between the groups (Fig. 4). Oxygenation was satisfactory in all patients during the study, the $Pa\text{O}_2$ increasing by an average of about 20–30% from the pre-operative value in all the treatment groups. There was no statistical difference between the groups. $Pa\text{CO}_2$ remained within physiological limits in all the groups throughout the study.

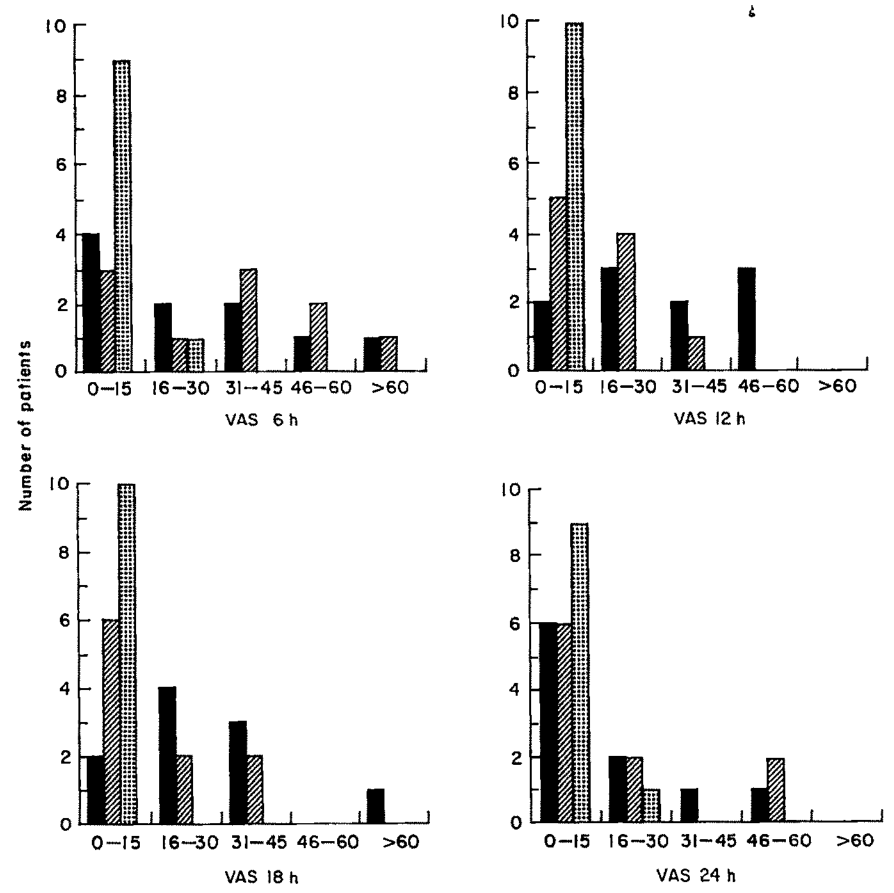

Fig. 2. Frequency distribution of pain scores at intervals during the 24 h after operation. ■, bupivacaine; ▨ fentanyl; ▩, mixture.

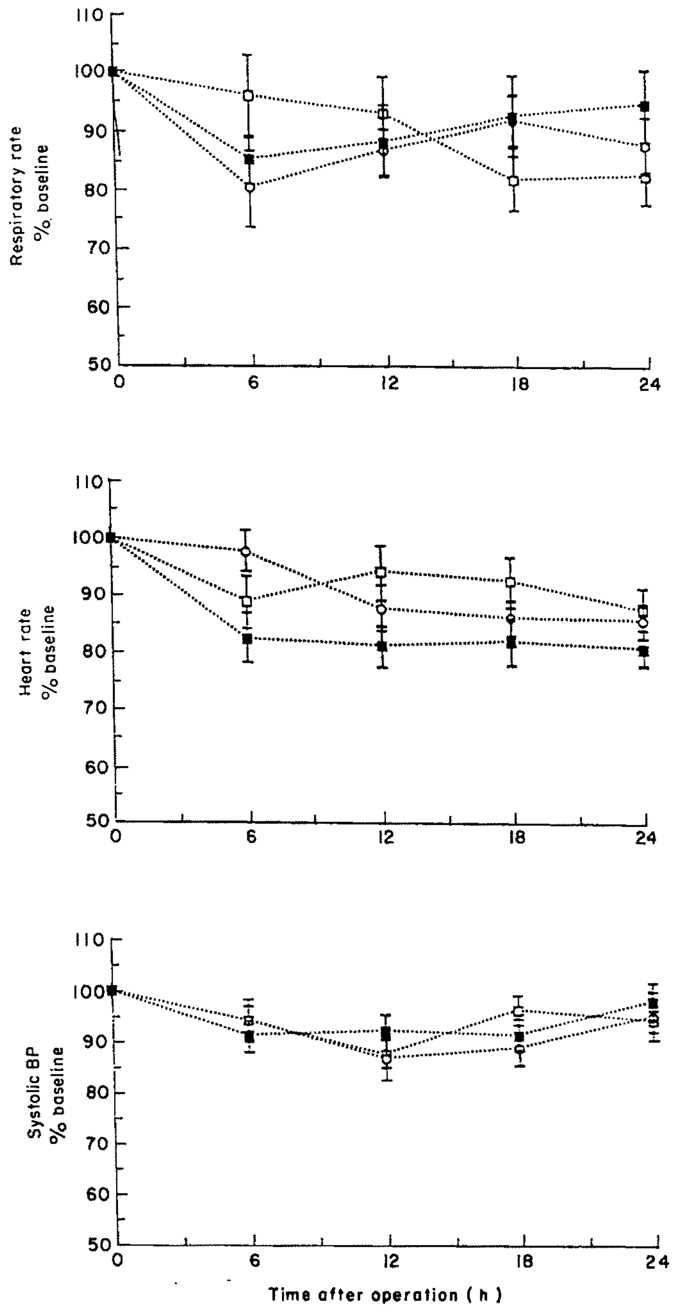

Fig. 3. Mean (SEM) respiratory rate, heart rate and systolic blood pressure % baseline at intervals during the 24 h after operation. □, bupivacaine; ○, fentanyl; ■, mixture.

Apart from one patient in the fentanyl group, there was no difference in the level of sedation between groups ($p > 0.05$). Emetic symptoms ranged from 20–50% between the groups, while pruritus only occurred in the group of patients who received fentanyl. Forty percent of the patients in the bupivacaine group complained of numbness of the trunk compared to 20% in the fentanyl group. The incidence of limb weakness was low in all the groups (Table 2).

Discussion

This study has demonstrated that postoperative analgesia provided by an epidural infusion of a mixture of bupivacaine and fentanyl is superior to analgesia provided by each drug alone. This excellent analgesia was achieved without significant side effects.

The group of patients who received the mixture of bupivacaine and fentanyl had very low pain scores with a median visual analogue score of 5 mm. This finding agrees with our earlier report [14]. This superior analgesia provided by the mixture may result from the combined effects of afferent neural blockade, selective spinal analgesia and central analgesic effects secondary to vascular absorption of fentanyl [16,17]. In our study, the patients in the 'mixture' group required less morphine from the PCA system than the other two groups, confirming the view that the combination treatment offered superior analgesia.

When epidural local anaesthetics are used alone after either thoracic [4,12] or upper abdominal surgery [2], anal-

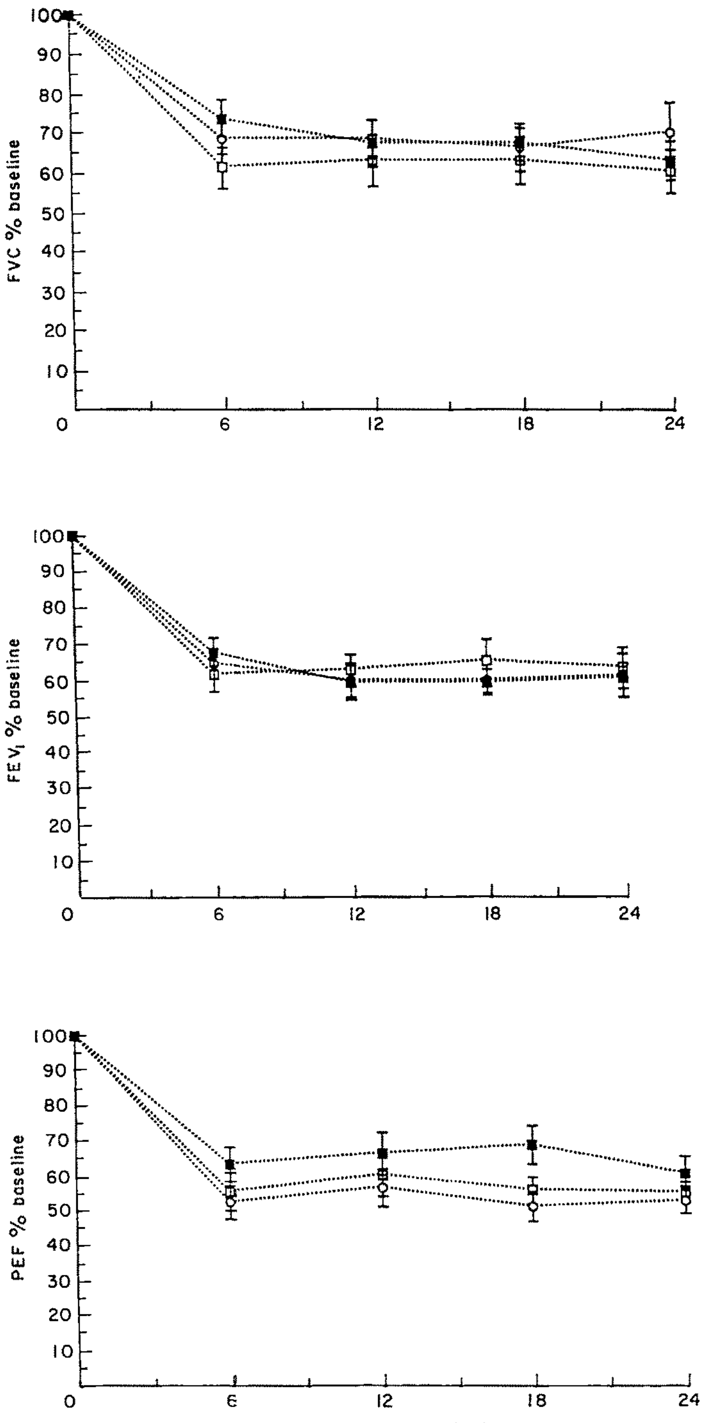

Fig. 4. Mean (SEM) FVC, FEV$_1$ and PEF% baseline at intervals during the 24 h after operation. ☐, bupivacaine; ○, fentanyl; ■, mixture.

gesia is unsatisfactory and is often accompanied by hypotension. Others report that thoracic epidural fentanyl offers satisfactory analgesia without hypotension when it is used after upper abdominal surgery [18,19] and thoracic surgery [20]. Hypotension can occur with a small infusion rate (6 ml.h^{-1}) of 0.5% bupivacaine if administered with morphine [21]. Circulatory changes after thoracic epidural bupivacaine 25 mg include a reduction in heart rate, arterial blood pressure and cardiac output [22]. In this study, use of continuous thoracic epidural bupivacaine 0.2% combined with fentanyl caused only a 5–10% reduction in both the heart rate and systolic arterial blood pressure. The absence of significant hypotension in this study could be because only a small dose of bupivacaine was given (maximum dose 10 mg.h^{-1} in a maximum volume of 5 ml.h^{-1}), thereby limiting the spread in the epidural space.

The important complication of extradural opioid administration is ventilatory depression [6–11]. This can occur either soon after administration [23,24] or have a delayed onset [25,26] depending on the lipophilicity of the opioid. In this study, no significant respiratory depression was noted in any of the three groups. This was probably due to the fact that the quantity of fentanyl being infused (maximum dose of 0.05 mg.h^{-1} in a maximum volume of 5 ml.h^{-1}) was too small to produce an effect even if it gained direct access to the brain via the basivertebral route.

Despite the elimination of pain, we found that the FVC, FEV_1 and PEF were all reduced to about 50–60% of their pre-operative values. This has been observed by other authors [12,27,28]. Various factors other than pain may be responsible. A neurohumoral component [21] was suggested, but Schulze *et al.* [29] in their study noted that despite using systemic indomethacin plus epidural bupivacaine and morphine, postoperative reduction in peak flow could not be prevented. Postoperative fatigue, a consistent complaint following abdominal surgery [30], may be involved in the pathophysiology of postoperative pulmonary dysfunction.

The incidence of side effects (oversedation, pruritus and emetic symptoms) were low when compared to previous reports [2–11,20]. There were only two reports of limb weakness in our study, one in the bupivacaine and the other in the combined bupivacaine and fentanyl group. The low incidence of symptomatic lower limb weakness is important for early mobilisation.

The placement of epidural catheters before induction of anaesthesia and before the administration of heparin was not associated with any neurological complications in our patients. The administration of heparin after epidural analgesia in patients undergoing vascular operations has been reported to cause epidural haematoma and cord compression [31]. This led to recommendations by some that epidural analgesia should be avoided whenever possible in patients receiving anticoagulants perioperatively. Other authors [32,33] have shown that epidural analgesia in patients receiving heparin during vascular operations was not associated with epidural haematoma and neurological damage.

A combined regional and general anaesthetic technique has advantages including attenuation of increased systemic vascular resistance with aortic cross clamping [34], and stable cardiovascular dynamics following cross clamp release [35]; our own observations during this study support these views. In addition, early tracheal extubation was possible because of good analgesia, thus avoiding prolonged mechanical ventilation.

In summary, infusion of bupivacaine and fentanyl epidurally is superior to either drug used alone in providing analgesia following abdominal aortic surgery. This was achieved with minimal side effects. This study supports the increasing use of thoracic epidural infusion analgesia in postoperative pain management.

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Fentanyl–prilocaine mixture for intravenous regional anaesthesia in patients undergoing surgery

M. T. PITKÄNEN, P. H. ROSENBERG, P. J. PERE, M. K. TUOMINEN AND T. A. SEPPÄLÄ

Summary

The effect of the addition of 0.1 mg or 0.2 mg fentanyl to 40 ml 0.5% prilocaine in intravenous regional anaesthesia of the arm was investigated in 37 patients in a randomised, double-blind study. The characteristics of the sensory and motor block were studied. There was no difference in the speed of onset of analgesia in the groups (mean latency approximately 4 min in each group). However, significantly more patients in the fentanyl 0.2 mg group (7/12) had complete anaesthesia at 15 min than in the fentanyl 0.1 mg group (1/13) and the control group (2/12) ($p < 0.05$). There were no differences in the incidence of tourniquet pain immediately before cuff deflation (tourniquet time 45–87 min). After cuff deflation, in those patients who complained of wound pain within 30 min, on average the pain appeared later in the fentanyl 0.2 mg group (six patients, mean 14.3 min) than in the control group (eight patients, mean 9.4 min) (ns). In the fentanyl groups, the incidence of central nervous system side effects was greater than in the control group (fentanyl 0.1 mg 7/13 patients, fentanyl 0.2 mg 6/12 patients, control 1/12 patients) ($p < 0.05$). The plasma concentrations of prilocaine after cuff deflation were higher, in a dose-dependent fashion, in the fentanyl groups than in the control group, but the concentrations of prilocaine and fentanyl did not correlate with the symptoms. Postoperative nausea occurred only in the patients who had received fentanyl.

Key words

Anaesthetics, local; prilocaine.
Analgesics; fentanyl.
Anaesthetic techniques, regional; intravenous.

Studies in animals indicate that there are opioid receptors in peripheral nerve tissue [1–3]. Joris *et al.* [4] demonstrated that fentanyl had an analgesic effect locally when injected into an inflamed paw of a rat. In isolated nerve studies, fentanyl has been shown to have an effect similar to that of local anaesthetics [5]. Intra-articular morphine has been found to be effective for postoperative pain relief after knee arthroscopy [6].

In volunteers, the addition of 100 μg fentanyl to either lignocaine [7] or prilocaine [8] for intravenous regional anaesthesia (IVRA) did not shorten the time to onset of pinprick analgesia or anaesthesia of the skin.

We studied the effects of adding 100 μg or 200 μg fentanyl to 40 ml 0.5% prilocaine for IVRA in patients having surgery in which the tourniquet time was about 60 min. Assessments of the onset and recovery of sensory and motor block, and of tourniquet pain, were made. In addition we measured the plasma concentrations of prilocaine and fentanyl so that they could be correlated with any symptoms which could possibly be attributed to drug toxicity occurring after cuff deflation.

Methods

The study protocol was approved by the ethics committee of the hospital and all patients gave their informed consent. Thirty-seven ASA grade 1 or 2 outpatients, scheduled for minor operations of the upper extremity, were studied in a randomised, double-blind fashion.

Patient monitoring included electrocardiogram (ECG), noninvasive blood pressure and pulse oximetry. An intravenous infusion of Ringer's acetate solution was started in a vein of the contralateral arm. A peripheral vein, on the arm to be operated on was cannulated (1.0 mm). The arm was exsanguinated using an Esmarch bandage and the proximal cuff of a double-cuffed tourniquet placed on the upper arm was inflated to 300 mmHg.

All patients received 40 ml 0.5% prilocaine (Citanest, Astra Pharm Corp, Södertälje, Sweden) plus fentanyl or saline, injected over 2 min. In the control group (12 patients) 4 ml of 0.9% sodium chloride was added to 40 ml 0.5% prilocaine. In the fentanyl 0.1 group (13 patients) the additions were 2 ml 0.9% saline and 2 ml fentanyl (0.1 mg)

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and in the fentanyl 0.2 group (12 patients), 4 ml (0.2 mg) fentanyl.

Onset and recovery of sensory block was tested by the pinprick method, with the skin of the opposite shoulder used as a reference point. The sensory block was tested over predetermined areas, selected to represent the innervation of the ulnar, median, radial and musculocutaneous nerves. Sensation of a sharp needle (short-bevel 27-G) as blunt was recorded as analgesia of the particular point and no sensation was recorded as anaesthesia. Motor block was measured using a manometer connected via a rubber tube to a balloon held in the palm, which the patient was asked to squeeze as hard as possible. The measurements were made 1, 3, 5, 10 and 15 min after the injection of prilocaine. Thirty min after the injection, the tourniquet pressure was changed over to the distal cuff and the subjective sensation of the tourniquet pressure was recorded. The sensory block was tested 3, 5, 10 and 15 min after deflation. In most patients, the recovery of motor block could not be tested because the hand and arm were bandaged. If pain was felt during the operation, alfentanil 0.5–1.0 mg was given. Midazolam (2.5–5 mg) was used for sedation, as required. Blood samples were taken from a vein in the contralateral arm, before injection, immediately before deflation, 2, 5, 12.5 and 20 min after deflation of the cuff. Prilocaine concentrations in each sample were measured using the gas chromatographic method described by Mather and Tucker [9].

In 16 randomly selected patients from the fentanyl 0.1 ($n = 8$) and the fentanyl 0.2 ($n = 8$) groups, plasma fentanyl concentrations were measured in the sample taken just before cuff deflation and from samples 2, 5 and 12.5 min after cuff deflation. Plasma fentanyl levels were determined by radioimmunoassay using commercially available kits (Diagnostic Products Corporation, Los Angeles, USA). Before analyses, serum samples were diluted (1 : 1) with a buffer consisting of 3.998 g of $NaH_2PO_4.2H_2O$, 0.7749 g of $Na_2PO_4.H_2O$, and 5.579 g of NaCl per litre of solution. The pH was 7.35, ionic strength 0.168, chloride and sodium concentrations 95.5 and 146 mmol.l^{-1} respectively. Standard curves were produced by using spiked and diluted serum samples; the curves were linear from 0.2 up to 10 ng.ml^{-1} fentanyl. Detection limit of the method was 0.15 ng.ml^{-1} fentanyl and intra-assay precision, expressed as coefficient of variation, was less than 5% at a concentration of 0.50 ng.ml^{-1} of fentanyl ($n = 8$).

Statistical analysis

ANOVA and Student's *t*-test were used for comparison of the mean values between the groups. Chi-square test and Fisher's exact test were used for comparison between the frequencies.

Results

Sensory and motor block

Fifteen min after the injection, two patients in the control group, one in the fentanyl 0.1 group and seven in the fentanyl 0.2 group had anaesthesia (no feeling of touch) in all the four test areas ($p < 0.05$) (Table 1). However, the average times to develop analgesia at these four spots did not differ between the groups (Table 2).

When surgery was started (20–25 min after the injection) no patient complained of pain resulting from the incision. The mean time to complete motor block was slightly shorter in the two fentanyl groups compared with that of the control group, but the difference was not statistically significant (Table 1).

Tourniquet pain

The tourniquet inflation times varied from 45 to 87 min, with no statistically significant difference between the groups (Table 1). In two patients in the control group and in three in the fentanyl 0.2 group, the tourniquet had to be deflated before the full hour had elapsed because the patient had great discomfort from the tourniquet and the surgery had finished.

Table 1. Characteristics of the block and recovery. Values are expressed as mean (SEM) and (range) as appropriate.

	Prilocaine plus saline ($n = 12$)	Prilocaine plus fentanyl 0.1 mg ($n = 13$)	Prilocaine plus fentanyl 0.2 mg ($n = 12$)
Complete block of all four test spots (no. of patients)	2	1	7*
Time to motor block; min	11.5 (1.2) (3–15)	8.4 (1.3) (3–15)	7.3 (1.3) (1–15)
Tourniquet time; min	61.8 (7.7) (49–75)	66.8 (8.9) (60–85)	64.3 (12.9) (45–87)
Pain from tourniquet no/mild/severe (no. of patients)	1/5/6	4/4/5	1/3/8
Sensation recovered; min	6.8 (1.1) (3–15)	9.1 (1.3) (3–15)	9.4 (1.4) (3–15)
Experienced pain; min after deflation	9.4 (2.0) (5–20) (8 patients)	10.8 (1.5) (5–20) (9 patients)	14.3 (2.0) (8–20) (6 patients)
Symptoms after deflation; no. of patients	1	7	6*

*$p < 0.05$.

Table 2. Characteristics of the sensory block. Mean time (min (SEM) and (range)) to pinprick analgesia (no sensation of sharp needle) in the area innervated by the relevant nerves.

	Prilocaine plus saline	Prilocaine plus fentanyl 0.1 mg	Prilocaine plus fentanyl 0.2 mg
Median nerve	9.2 (1.58) (1–15)	9.4 (1.60) (1–15)	8.5 (1.43) (3–15)
Musculocutaneous nerve	4.6 (1.05) (1–10)	4.1 (0.86) (1–10)	4.7 (1.44) (1–15)
Radial nerve	6.6 (1.59) (1–15)	4.4 (0.82) (1–10)	4.3 (0.85) (1–10)
Ulnar nerve	7.4 (1.76) (1–15)	5.5 (1.35) (1–15)	6.2 (1.27) (1–15)

There was no difference between the groups in the incidence of discomfort or pain resulting from the tourniquet, as assessed immediately before cuff deflation (Table 1). In fact, eight of the 12 patients in the fentanyl 0.2 group experienced severe tourniquet pain. Alfentanil was administered to treat tourniquet pain in one patient each in the control and the fentanyl 0.1 groups and in two patients in the fentanyl 0.2 group.

Recovery

Times to recovery of sensation to pinprick after tourniquet cuff deflation did not differ between the groups. Fewer patients reported postoperative wound pain within the first 30 min and pain appeared later in the fentanyl 0.2 group (6/12 patients) than in the fentanyl 0.1 group (9/13) or the control group (8/12) (Table 1), but this did not reach statistical significance.

Symptoms

Only one patient in the control group, compared with seven and six in fentanyl 0.1 and fentanyl 0.2 groups respectively, had central nervous system symptoms after deflation of the tourniquet cuff ($p < 0.05$). These symptoms consisted mostly of light-headedness and dizziness, but two patients in each of the two fentanyl groups experienced nausea which lasted from 10 min to 2 h.

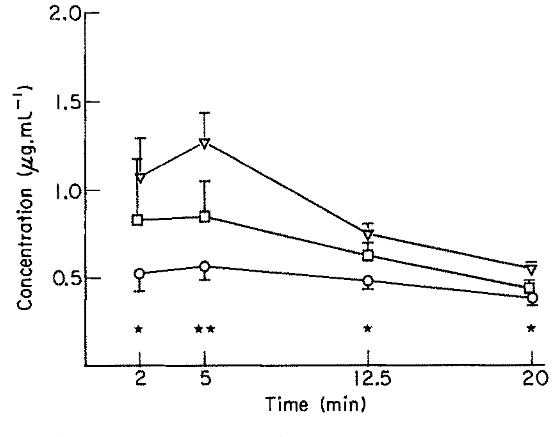

Fig. 1. Plasma concentrations of prilocaine in the groups. Error bars indicate SEM (in one direction only). * $p < 0.05$, ** $p < 0.01$ between saline and fentanyl 0.2 mg groups. ▽, fentanyl 0.2 mg; □, fentanyl 0.1 mg; ○, saline.

Plasma concentrations (Figs 1 and 2)

The plasma concentrations of prilocaine were higher, in a dose-dependent fashion, in the two fentanyl groups than those in the control group (Fig. 1). Prilocaine concentrations in the fentanyl 0.2 group were significantly ($p < 0.05$) greater than those in the control group for all of the sampling times. There was no correlation between the prilocaine concentrations and the occurrence of central nervous symptoms.

Three patients (fentanyl 0.2 group) had low (0.054–0.134 μg.ml^{-1}) concentrations of prilocaine in the plasma before deflation of the tourniquet. The post-deflation fentanyl concentrations are shown in Figure 2. The fentanyl concentrations were higher in the fentanyl 0.2 group but there was no relationship between the fentanyl levels and the absence or presence of wound pain, or with the central nervous system symptoms (including nausea), after tourniquet cuff deflation.

Discussion

When 0.2 mg of fentanyl was added to 40 ml 0.5% prilocaine for IVRA, more patients had complete block in all test areas of the arm than after the addition of 0.1 mg fentanyl or saline to the prilocaine 15 min after injection. However, the times taken to develop analgesia in the test points did not differ between the groups and no pain was experienced during surgery in any of the patients.

The lack of significant differences in the development of

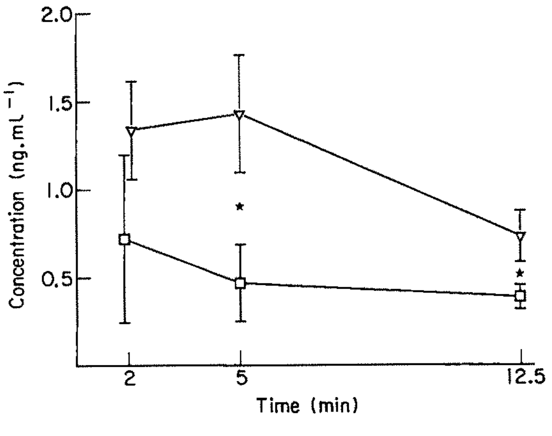

Fig. 2. Plasma concentrations of fentanyl. Error bars indicate SEM. * $p < 0.05$. ▽, fentanyl 0.2 mg; □, fentanyl 0.1 mg.

the block are in accord with the findings of Armstrong *et al.*, who observed that the addition of 0.1 mg fentanyl to prilocaine for IVRA did not influence the block [8]. Fentanyl did not prevent the pain or discomfort secondary to the tourniquet in our surgical patients. This also corresponded with the findings of Armstrong *et al.*, in volunteers [8]. However, in that study, the tourniquet time was 20 min, which was only about a third of that of our own study.

It appears that the effect of fentanyl reported in isolated nerve conduction studies [5] does not contribute significantly in the clinical situation, in which the potent effect of the local anaesthetic clearly overwhelms that of the opioid. Other studies have shown that, when a lower dose of a local anaesthetic was used (40 ml of 0.25% lignocaine), the addition of 0.1 mg fentanyl did not improve the IVRA block characteristics in a clinically significant manner either [7].

Central nervous system symptoms were experienced after cuff deflation more frequently when fentanyl had been used in the IVRA. The acute symptoms (lightheadedness, dizziness) were similar to those described by Armstrong *et al.* [8] and are typical of symptoms attributable to local anaesthetic toxicity. Even in the presence of sedation produced by relatively large doses of an opioid (morphine) and diazepam, symptoms of central nervous system toxicity produced by local anaesthetics (lignocaine) can normally be easily recognised [10]. The nausea experienced by several patients in the fentanyl groups, which in some cases lasted for 2 h, was probably due entirely to the effect of opioid.

It is of interest that prilocaine concentrations were greater in the patients who had received fentanyl in the mixture than in those who had received saline. Similar observations have been made by Valli *et al.* [11] when morphine was used as a premedication instead of diazepam before IVRA. Fentanyl has a vasodilator effect [12]. Thus it is possible that this effect of fentanyl on the veins resulted in a more rapid washout of local anaesthetic from the extremity after cuff deflation, hence producing higher plasma concentrations. In all three groups, by 20 min, the mean plasma concentrations were approaching each other (Fig. 1). Plasma concentrations of prilocaine were well below the toxic limits. Fentanyl concentrations immediately after cuff deflation were usually at a level which has been reported to produce postoperative analgesia (0.63–1 $ng.ml^{-1}$) [13,14]. In the fentanyl 0.2 group at 12.5 min, plasma fentanyl levels were still, on average, sufficient for analgesia (0.7 $ng.ml^{-1}$). This may have been responsible for the delay in the appearance of wound pain after cuff deflation in the patients from the fentanyl 0.2 group.

In conclusion, although the addition of fentanyl to 0.5% prilocaine improved the development of anaesthesia in IVRA, to a certain extent, the difference was not of clinical relevance and the resultant surgical analgesia was similar to that produced by prilocaine alone. In addition, since the incidence of side effects was high in the fentanyl groups, its addition to a local anaesthetic solution for IVRA is of no benefit.

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Transdermal hyoscine with patient-controlled analgesia

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Summary

Transdermal hyoscine (Scopoderm TTS CIBA) was compared with placebo in 67 patients receiving postoperative analgesia via a patient-controlled analgesia system. All patients underwent an abdominal hysterectomy and had a standard anaesthetic. They were followed up in recovery and daily for 3 days postoperatively. Fewer patients in the hyoscine group suffered emetic sequelae in recovery and on the third postoperative day ($p < 0.05$). The hyoscine group received half the number of supplementary antiemetic doses compared to placebo. However, despite transdermal hyoscine there was still a high (78%) incidence of nausea and vomiting. The only significant ($p < 0.05$) increase in side effects attributable to hyoscine was a higher reported incidence of visual disturbance on the second day.

Key words

Complications; nausea, vomiting.
Antiemetic; transdermal hyoscine.
Analgesia; patient controlled analgesia.

Patient-controlled analgesia (PCA) is used frequently in our hospital but we have observed a high incidence of nausea and vomiting with this technique [1]. This may in part be due to a reluctance to administer intramuscular antiemetics. Antiemetics are not administered routinely with PCA, unlike when intramuscular opioids are used. Clearly an alternative to the intramuscular route of administration of antiemetics would be desirable. Transdermal hyoscine has been shown to be an effective antiemetic for motion sickness [2–4]; however, its use for preventing postoperative nausea has not been so well demonstrated [5–7]. These studies used intramuscular postoperative analgesic regimens which result in peaks and troughs of opioid blood concentration. Patients receiving PCA are prescribed small doses of analgesia which they are able to self-administer at frequent intervals and may be expected to have a more constant blood concentration. Transdermal drug delivery also offers a mechanism to achieve and maintain a relatively constant drug concentration [8]. This was the rationale for studying the effectiveness of transdermal hyoscine in patients receiving PCA.

Method

Patients aged between 18 and 65 years and of ASA status 1 or 2 requiring general anaesthesia for abdominal hysterectomy were recruited into the trial. The study was approved by the Hospital Medical Ethics Committee and written informed consent was obtained. The patients were randomly allocated to receive either a hyoscine transdermal patch or a matching placebo patch. On the evening before surgery the use of PCA was explained and patients were informed that an intramuscular antiemetic would be available on request postoperatively.

Oral temazepam 20 mg was given 2 h pre-operatively and the patch, or placebo, applied behind the ear. The placebo was a standard waterproof dressing (Johnson and Johnson) and each hyoscine patch was covered by a similar dressing, so that its identity could not be distinguished from placebo by patient or assessor. The patches were applied by a nurse who was not involved with subsequent assessment.

A standard anaesthetic was given consisting of induction with thiopentone 3–5 $mg.kg^{-1}$, followed by fentanyl 3–5 $\mu g.kg^{-1}$ and a bolus of vecuronium 0.1 $mg.kg^{-1}$ with increments as necessary. Anaesthesia was maintained using enflurane in 70% nitrous oxide and 30% oxygen. Residual muscular relaxation was antagonised at the end of surgery with atropine 1.2 mg and neostigmine 2.5 mg. No patient was given pre- or intra-operative antiemetics.

Postoperative analgesia was provided by PCA started in the recovery room. The PCA was set to deliver a 1 mg bolus of morphine with a lockout time of 5 min. No

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Table 1. Patient characteristics with pre-, per- and postoperation details. Data expressed as mean (SEM) [range].

	Hyoscine group ($n = 37$)	Placebo group ($n = 30$)
Age; years	45 (13) [28–64]	45.5 (14) [31–63]
Weight; kg	68.5 (1.5) [49–86]	68 (2) [54–97]
Duration of pre-operative starvation; min	530 (18) [300–810]	550 (24) [360–900]
Duration of anaesthetic; min	72 (5) [40–120]	62 (3.5) [30–105]
Total dose of morphine; mg	77.5 (6.5) [26–210]	82.5 (7.5) [31–149]

Table 2. Incidence of nausea and vomiting (number (percentage)).

	Recovery		Day one		Day two		Day three	
	Hyoscine	Placebo	Hyoscine	Placebo	Hyoscine	Placebo	Hyoscine	Placebo
No nausea/vomiting; score 0	30 (81)	16 (53)	13 (35)	5 (16.6)	26 (62)	17 (57)	34 (92)	20 (66.6)
Nausea; score 1	6 (16)	12 (40)	11 (30)	11 (36.6)	11 (30)	7 (23)	1 (3)	5 (16.6)
Vomiting/retching; score 2	1 (3)	2 (7)	13 (35)	14 (46.6)	3 (8)	6 (20)	2 (5)	5 (16.6)

background infusion was given. Nausea and vomiting were treated with an intramuscular injection of cyclizine 50 mg on request. All patients were assessed in the recovery room and on the first, second and third days postoperatively. The patches were removed after 72 h. Assessments were made in recovery by the nursing staff and on the wards by members of the acute pain team.

Nausea was assessed on a three-point scale: no nausea 0, nausea 1 and vomiting or retching 2. Patients were directly questioned about potential side effects of hyoscine including: dry mouth, visual disturbance or any 'strange or unusual sensations'. The number of doses of antiemetic and total dose of morphine used were also recorded.

Statistical analysis of the results was carried out using the unpaired *t*-test for demographic data, Fisher's exact test for side effects, Welcher's test for the number of antiemetic doses given and Chi-squared test for emetic scores. Statistical significance was taken as $p < 0.05$.

Results

Seventy-two patients were recruited into the trial but five were later withdrawn: two patients had problems with the PCA (one severe itching, one was unable to operate it) and both were converted to intramuscular analgesia, one patient was inadequately followed up, one patch was accidentally removed and one patient developed an allergy to the dressing. Of the remaining 67 subjects, 37 were in the active group and 30 in the placebo group. Age, weight, duration of pre-operative starvation, duration of operation and total dose of morphine were similar in both groups (Table 1). There was a significant ($p < 0.01$) difference in the number of antiemetic doses given between the two groups; the hyoscine group received on average 1.03 supplementary doses, the placebo group received over twice as many with a mean of 2.23 doses.

Table 3. Overall incidence of emetic sequelae.

	No Nausea/ vomiting	Nausea	Vomiting/ retching
Hyoscine $n = 37$	22%	35%	43%
Placebo $n = 30$	13%	33%	53%

Table 2 shows the incidence of nausea or vomiting for the four time periods in the two groups. For statistical analysis, patients with an emetic score of 1 or 2 were combined and Chi-squared calculated. There was a significant ($p < 0.05$) reduction in emetic sequelae in recovery and on the third postoperative day in the hyoscine groups. The percentage of patients experiencing nausea or vomiting at any time in the first 3 days postoperatively is shown in Table 3. Some degree of nausea or vomiting was present in 88% of the placebo group and 78% of the hyoscine group.

The incidence of dry mouth, visual disturbance and any 'unusual sensations' on the first, second and third postoperative days is shown in Table 4. Significantly ($p < 0.05$) more patients reported visual disturbance on the second day in the hyoscine group.

Discussion

We have demonstrated that transdermal hyoscine reduced the incidence of postoperative nausea and vomiting in the recovery room and on the third postoperative day. Uppington *et al.* [6], in a similar patient group receiving intramuscular opioids, found an improvement in emetic scores in the first 24 h only. Jackson *et al.* [5], with a more diverse group of patients, found improvement in the maximal degree of recorded emesis within the first 24 h. Reduction of emesis early in the recovery period is important as this will lessen the chance of aspiration of gastric contents. Koski *et al.* [7] failed to demonstrate any improvement on emetic scores with hyoscine; however, these patients had varying operations, anaesthetics and analgesic regimens, such that a therapeutic effect may have been missed despite large patient numbers.

The pattern of improvement in emetic scores in our patients does not suggest that hyoscine had an antiemetic effect with PCA, as patients would be using relatively little PCA morphine in recovery and at 72 h. Recently Bailey *et al.* [9] demonstrated the effectiveness of transdermal hyoscine after laparoscopy in outpatients. An antimotion

Table 4. Patients experiencing side effects (number (percentage)).

	Day one Hyoscine	Day one Placebo	Day two Hyoscine	Day two Placebo	Day three Hyoscine	Day three Placebo
Dry mouth	35 (96)	27 (90)	21 (57)	17 (57)	11 (30)	6 (20)
Visual disturbance	14 (38)	9 (30)	15 (41)*	6 (20)	8 (22)	5 (17)
Any unusual sensations	5 (14)	5 (17)	3 (8)	1 (3)	3 (8)	2 (7)

* $p < 0.05$ compared to placebo.

sickness effect may be important in both outpatients and our own study.

The hyoscine group received a significantly lower number of supplementary doses of antiemetic; less than half of the placebo group. This suggests that the patch may have been having greater beneficial effect than suggested by the well established emetic scoring system used [10]. Other authors have tried to score the severity and frequency of nausea and/or vomiting [6,7]. Overall the number of supplementary antiemetic doses given in both groups appears low compared with the incidence of nausea and vomiting. Patients with PCA may be offered less antiemetic or may be less likely to request an intramuscular injection. There was an increased incidence of visual disturbance in the hyoscine group on day two but no other differences in the side effects at any other time. Studies on inpatients undergoing major operations have been similar with regard to side effects. Uppington *et al.* [6] also showed increased incidence of visual disturbance at 48 h, whilst Koski *et al.* [7] and Jackson *et al.* [5] showed no significant difference. In contrast, studies on outpatients have a high incidence of side effects [9,11].

In our patients, the overall incidence of nausea and vomiting was high: 78% in the hyoscine group, 88% in the placebo group. This may have been due to a number of factors: no pre- or intra-operative antiemetic, direct questioning, female patients [12], abdominal operations [13] and a long assessment period including recovery. Our figures are comparable with other studies [14] and demonstrate the high incidence of postoperative emesis that has received editorial comment [15].

We conclude that despite an improvement in emetic scores the incidence of nausea and vomiting was so high as not to recommend transcutaneous hyoscine as a sole agent in the management of postoperative nausea and vomiting in patients receiving PCA.

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Anaesthesia, 1992, Volume 47, pages 402–404

CASE REPORT

Patient-controlled analgesia

A serious incident

E. R. GROVER AND M. L. HEATH

Summary

A patient received a massive overdose of papaveretum intravenously (estimated to be 180 mg) when the glass syringe of a patient-controlled analgesia machine disengaged from the drive mechanism. She was successfully resuscitated. The pump, on loan from the supplier, had passed a brief evaluation by the infusion pump test house designated by the Medical Devices Directorate of the Department of Health; it has since been withdrawn. It is recommended that patient-controlled analgesia equipment should be placed at or below patient heart level. The Department of Health is called on to institute a full, independent evaluation scheme for patient-controlled analgesia equipment.

Key words

Analgesia; patient-controlled.
Complications; accidents.

Patients have received the benefit of patient-controlled analgesia (PCA) in Lewisham Hospital for many years, initially using Cardiff Palliator pumps. More recently, a major study has been undertaken of psychological factors and effectiveness of PCA, using devices on loan from several manufacturers. This extended the use of PCA to a wider group of surgical patients and the results (some of which have been published [1]) have generated much enthusiasm for PCA within the hospital. Education and training for nurses on the surgical wards have attempted to give them an understanding of the principles of the technique and confidence in it; however, it has been difficult to ensure a uniform high level of understanding and the pumps have remained the primary responsibility of the anaesthetists. There had been no recorded serious untoward incidents before that described below. It has been our policy to start PCA in the recovery room and to transfer patients, when conscious and comfortable, to our postoperative wards which are of the open 'Nightingale' style. Observations of pulse, blood pressure and respiratory rate are made at increasing intervals, depending on the patient's general condition and the nature of the surgery.

We report a serious incident involving the use of a PCA device and discuss certain implications for the care of patients receiving PCA and for equipment testing programmes.

Case history

A 17-year-old female, ASA grade 1, body mass 83.5 kg, was admitted for elective cholecystectomy in June 1990. During her pre-operative anaesthetic assessment, the concept of PCA was discussed and she gave informed consent to the use of a Bionica MDS 110 PCA machine (on loan from International Medication Systems (UK) Ltd), for postoperative analgesia. A sample of the equipment had been checked at their request by the test centre at Bath, which is responsible for the Department of Health (DH) evaluation programme for infusion pumps. However, there is, as yet, no full evaluation programme for PCA equipment. Full training in its use had been received from the sales representative and the equipment had been tested and logged by the hospital Electronic Medical Equipment department who found it satisfactory, although noted that its construction was somewhat insubstantial.

General anaesthesia was induced with propofol and neuromuscular blockade established with vecuronium. The trachea was intubated and the lungs were ventilated with 60% nitrous oxide in oxygen with isoflurane; analgesia was provided by fentanyl 350 μg. Surgery lasted 1 h and was uneventful. The wound was infiltrated with 20 ml bupivacaine 0.5% and she was transferred to the recovery room after reversal of residual neuromuscular blockade and awake extubation in the lateral position.

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The PCA system was prepared by charging the supplied 10 ml glass syringe with papaveretum 200 mg and placing it in the drive mechanism. The delivery tubing was attached to the side-port of a Vygon Y-connector with an integral one-way valve. After priming, this was inserted between the intravenous giving set and the 16-G cannula, sited on the dorsum of the left hand. The machine was programmed according to the manufacturer's instructions to deliver a bolus dose of 4 mg with a lockout period of 10 min and no background infusion. Her postoperative state stabilised rapidly and she was transferred to the surgical ward, conscious and orientated, 1 h later.

Routine postoperative observations were recorded and she remained stable over the next 3 h. She was then discovered to be apnoeic and cyanosed, with no palpable pulse. Cardiopulmonary resuscitation was started and a cardiac arrest alert issued. On arrival, the anaesthetist found her to be unconscious but rousable, with pin-point pupils. She had a good pulse volume, blood pressure 180/100 mmHg and severe bradypnoea. It was then noted that the PCA machine was suspended from the infusion stand, in its protective case, about 60 cm above the patient. Inspection of the syringe revealed it to be empty, with the plunger fully home despite the fact that the plunger carriage was still near the start of its travel.

The patient responded well to naloxone 200 μg given intravenously, becoming alert with normal vital signs. However, she required a maintenance infusion of naloxone over a period of 4 h. She was established on an alternative PCA machine which she did not activate for a further 11 h, thereafter her hourly consumption of papaveretum was approximately 10 mg. She made an otherwise uneventful recovery and was discharged on the fifth postoperative day. The sales representative and marketing director responsible for the pump concerned in the incident were alerted promptly to the accident. They were extremely concerned and volunteered all possible help. All other similar pumps were promptly located and withdrawn from use. Tests undertaken by the Medical Devices Directorate of the DH on the pump showed no fault in the programme or accuracy of the pump; however, in certain positions, the syringe plunger became disengaged easily from the drive mechanism allowing syphoning of the contents to occur. A Hazard Warning Notice (HC(HAZARD)(91)9) was issued on 14 March 1991, approximately 9 months after the incident.

Discussion

This event reinforces our belief that the safety of the technique, outside the recovery area, is entirely dependent on its basic principle and that this must be understood by everyone concerned. We include relatives as 'concerned' persons since unauthorised activation of a PCA pump by a patient's wife, when she interpreted snoring as grunts of pain, has on one occasion led to an episode of mild respiratory depression. We do not specify any additional special postoperative monitoring for patients receiving PCA since we consider that the method is intrinsically at least as safe as administration of opioid by intramuscular injection and that no form of intermittent observation will detect the occasional, very rare, instance of major pump malfunction. Other hospitals report difficulty in maintaining more frequent nursing observation of respiratory rate. Notcutt and Morgan, reporting on 1000 patients treated in a district general hospital, records only two instances of naloxone treatment in the absence of a background infusion [2]. One patient had a slow respiratory rate and had received doxapram before PCA was instituted; in the other the treatment given was judged 'unnecessary'. Twelve patients whose rate fell below the prescribed limits apparently were neither treated nor had their PCA regimen altered. It is not surprising if busy nurses accord a low priority to quantifying an event which apparently provokes little response from the medical team. Catley and colleagues [3] demonstrated that respiratory rate is a poor indicator of respiratory depression.

This case report illustrates the absolute necessity of good continuous general observation: any delay in noticing our patient's collapse might have proved fatal. Whilst it has been suggested that patients receiving PCA would best be nursed in a high dependency unit (HDU), restriction of the technique to relatively expensive facilities that have yet to become widespread will deny many patients its great benefits. The safety record of other sophisticated pain relief systems [4,5] suggests that they should indeed be restricted to areas with a higher concentration of staff and monitoring equipment: recovery rooms, HDUs and ITUs. Clearly, spare capacity in any such area may be well utilised in caring for patients receiving PCA immediately postoperatively. However, at least one system is now available [6] which allows the patient to be fully ambulant and even take a shower; these advantages will be most appreciated at a stage of recovery more appropriate to a general ward. Hospital protocols should be sufficiently flexible to allow sensible judgements to be made.

Two reports of dangerous overdosage which occurred as a result of equipment malfunction (as opposed to incorrect programming) during PCA are known to us. In one [7] the pump concerned required prefilled glass vials of analgesic solution and a crack in one of these allowed solution to syphon into the patient. The resultant respiratory depression was successfully treated. Current models of this manufacturer's pumps now use plastic syringes and have positive engagement of the syringe in the drive mechanism; the use of dedicated disposable tubing incorporating an antisyphon device is also recommended. The other incident [8] occurred several years ago in the USA. Insufficient information was available, but 'runaway' infusion from an unspecified make of pump was assumed to be responsible for a fatal accident as a result of a massive overdose of pethidine.

The weight and ease of movement of the plungers of glass syringes make syphoning more likely to occur should other conditions favour it; in addition glass syringes or vials are more easily broken than plastic ones. On the other hand, the lower level of friction allows the occlusion pressure of pumps which use them to be set at lower, and thus arguably safer, levels. Glass is considered to be a more suitable material for prolonged contact with drug solutions, whereas adsorption of fentanyl has been demonstrated with plastic syringes and elastomeric balloon reservoirs used in PCA devices [9]. However, this study showed that the fall in delivered drug concentration (of approximately 11%) happened within the first few hours. Since interindividual variation in dose requirement is one to two orders higher than this [10] and compensation is an intrinsic element of the system, drug adsorption onto these materials is probably clinically insignificant. The weight of glass syringes is a disadvantage in systems designed to be attached to patients' clothing. Whatever the mechanism, syphoning accidents can be eliminated if the drug reservoir is routinely kept at or below the patient's heart level.

We remain extremely concerned that the routine check procedures of the DH test centre did not detect the possiblity of disengagement of the syringe from the drive mechanism. It is not entirely clear where medicolegal responsibility would have lain had the patient sustained any lasting ill effects. The rapid expansion in PCA use makes an irresistible case for a full, independent evaluation programme of equipment to be instituted by the Department of Health.

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CASE REPORT

Anaesthesia for cardiac surgery in children with nemaline myopathy

T. ASAI, K. FUJISE AND M. UCHIDA

Summary

Nemaline myopathy is a rare congenital myopathy associated with skeletal deformities and respiratory complications. Three children with nemaline myopathy who underwent cardiac surgery are described where the heart rate decreased during induction of anaesthesia and body temperature increased during or after the surgery. The anaesthetic implications in the management of patients with nemaline myopathy are discussed.

Key words

Anaesthesia; paediatric.
Complications; nemaline myopathy, bradycardia.
Surgery; cardiac.

Nemaline myopathy, first described in 1963 by Shy *et al.* [1] and by Conen *et al.* [2], is a rare congenital myopathy characterised by the appearance of rod-like structures (nemaline rods) in muscle fibres. Typically weakness and hypotonia appear in early childhood, and the disease has a benign, nonprogressive or slowly progressive course; however, there are several reports of fatal cases [3–6]. Nemaline myopathy can present at any age, but if respiratory complications occur in the neonate, prognosis is relatively poor.

Any muscle can be affected, including the pharyngeal muscles, the diaphragm, and the intercostal muscles. Difficulty in swallowing, aspiration of food, and restrictive ventilatory disturbance may occur because of weakness of these muscles, which can lead to malnutrition, recurrent pneumonia, and respiratory insufficiency. Spinal deformities may further limit pulmonary function.

Skeletal abnormalities are frequently associated with this disease; these include high-arched palate, long dysmorphic face, malocclusion, prognathism, kyphoscoliosis, lumbar lordosis, congenital dislocation of the hip, joint contractures, and pes cavus [2, 3, 6, 7].

Congenital heart disease has been diagnosed clinically in a few patients: ventricular septal defect (VSD), aortic regurgitation, patent ductus arteriosus, mild infundibular pulmonary stenosis, and anomalous papillary muscle [5–9].

There have been only two reports on the anaesthetic implications of this disease. One report described the response to muscle relaxants in a young patient, which showed some resistance to suxamethonium but with a normal response to pancuronium. The other report described two sisters who underwent general anaesthesia without muscle relaxants. Both had severe restrictive ventilatory disturbance but there was no respiratory complication.

We report the management of anaesthesia for cardiac surgery in three children with nemaline myopathy.

Case histories

Case 1

A 13-month-old girl (height 61.5 cm, weight 4.7 kg) was scheduled for surgical repair of an atrial septal defect (ASD). She had hypotonia and muscle weakness. Her oral intake was inadequate because of poor sucking and swallowing, and she had experienced recurrent episodes of pneumonia, dyspnoea, and vomiting from 2 weeks of age. Her face was long and slender with hypertelorism; she had a high-arched palate, micrognathia, a webbed neck, and low-set ears. Congenital dislocation of the hip, pes cavus and long fingers were also present, but the spine was straight. Serum creatine kinase (CK) levels were persistently elevated, with the MM isozyme predominant. Serum aldolase and lactic dehydrogenase (LDH) levels were also elevated.

Her paternal family history was of interest. Her father had a mild kyphosis; one of his male cousins, who had an unknown myopathy, died at 20 years of age; a female cousin has hypertelorism and strabismus, while two female

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cousins died of cardiac disease in infancy; a male cousin had cerebral palsy and died at 10 years of age. One of the patient's cousins died shortly after birth because of congenital anomalies which resulted in a total absence of bony ossification. Most of the patient's paternal relatives had asthma or atopic disease. Her maternal family history was unremarkable. No family history of malignant hyperthermia was elicited.

Atropine 0.02 mg and hyoscine 0.02 mg intramuscularly and chloral hydrate 250 mg rectally were given 45 min before the induction of anaesthesia. On arrival in the operating theatre, the arterial blood pressure was 100/64 mmHg, heart rate 142 beat.min^{-1}, respiratory rate 40 breath.min^{-1}, and body temperature 36.6°C. Anaesthesia was induced intravenously with diazepam 1 mg and fentanyl 50 μg in divided doses. Muscle relaxation was achieved with pancuronium 0.8 mg. The lungs were easily ventilated using a mask. The blood pressure and the heart rate remained stable. During laryngoscopy the heart rate decreased to 70 beat.min^{-1}, which quickly responded to atropine 0.05 mg given intravenously.

Anaesthesia was maintained with high-dose fentanyl and diazepam. The anaesthesia and operation proceeded without further incident, and the patient was transferred to the Intensive Care Unit (ICU). The body temperature was stable during surgery, but soon after arrival in the ICU, it increased to 38°C and remained elevated for 2 days. Since the patient was able to breathe adequately and was fully responsive, her trachea was extubated on the fourth postoperative day. There was no airway problem after the extubation. She was discharged 10 days later and made an uneventful recovery.

The diagnosis of nemaline myopathy was made by subsequent clinical investigation and muscle biopsy.

Case 2

A 2-year-old boy (height 83 cm, weight 10.5 kg) with an ASD was the younger brother of patient 1. He also had facial dysmorphism, a high-arched palate, webbed neck and low-set ears, in addition to bilateral cryptorchidism. Serum CK, LDH, and aldolase levels were persistently elevated. The diagnosis of nemaline myopathy was made by clinical investigation and muscle biopsy. Surgical repair of the ASD was planned, but it was postponed once because of pneumonia. He underwent surgery one month later.

Diazepam 5 mg and hyoscine 0.01 mg intramuscularly and chloral hydrate 500 mg rectally were given 45 min before the induction of anaesthesia. On arrival in the operating theatre, the arterial blood pressure was 108/62 mmHg, heart rate 138 beat.min^{-1}, respiratory rate 24 breath.min^{-1}, and body temperature 36.8°C. A pulse oximeter showed a saturation of 99%. Anaesthesia was induced with diazepam 2 mg and fentanyl 200 μg; pancuronium 2 mg was given for muscle relaxation. The heart rate gradually decreased to 116 beat.min^{-1}, and the blood pressure to 98/52 mmHg. The lungs were easily ventilated using a mask. The heart rate abruptly decreased to 62 beat.min^{-1} when the patient's mouth was opened for laryngoscopy, but it returned to normal promptly with mouth closure. Since another attempt was made with the same results, atropine 0.15 mg was given intravenously, after which the heart rate did not decrease upon mouth opening. However, the heart rate fell to 55 beat.min^{-1} when the trachea was intubated, but then returned to normal. Throughout the procedure, the pulse oximeter showed a saturation of 99%. Fifteen minutes after the induction of anaesthesia, the patient's rectal temperature rose to 37.8°C but decreased to 36.8°C with body cooling for 30 min. During the postcardiopulmonary bypass period, the rectal temperature started to rise again, and it was 38.2°C at the end of the surgery. The patient was transferred to the ICU where his temperature gradually decreased to 36.8°C. The postoperative course was otherwise uneventful, and he was discharged 12 days later.

Case 3

A 14-month-old boy (height 75 cm, weight 8.2 kg) with a VSD and mild pulmonary stenosis was scheduled for surgical repair of the VSD. He had no skeletal malformations except pectus excavatum, but a reduction in muscle mass of the lower extremities and developmental retardation were present. His family history was non-contributory. Serum CK, LDH, and aldolase levels were elevated. The diagnosis of nemaline myopathy was made by muscle biopsy.

Hyoscine 0.1 mg intramuscularly and chloral hydrate 250 mg rectally were given 45 min before the induction of anaesthesia. On arrival in the operating theatre, the arterial blood pressure was 110/54 mmHg, heart rate 140 beat.min^{-1}, respiratory rate 36 breath.min^{-1}, and body temperature 37.0 °C.

Anaesthesia was induced with diazepam 1 mg and fentanyl 180 μg in divided doses; pancuronium 0.8 mg was given for muscle relaxation. The heart rate transiently slowed to 70 beat.min^{-1} when the trachea was intubated, then returned to 122 beat.min^{-1}. The pulse oximeter indicated a saturation of 99%. Anaesthesia was maintained with high-dose fentanyl and diazepam. The operation proceeded uneventfully, and his recovery from anaesthesia was also unremarkable. At no time during the operation did his temperature rise above 37°C. The patient was transferred to the ICU, and 2 h after his arrival, his body temperature increased to 38°C and remained elevated for 2 days. Since he was fully awake and responsive, his trachea was extubated on the second postoperative day. He was discharged 2 weeks later.

Discussion

Nemaline myopathy has some important implications in anaesthetic management; difficulty in tracheal intubation may occur because of facial dysmorphism. Careful pre-operative evaluation of the airway is needed, and if a difficult intubation is anticipated, awake intubation or the use of the fibreoptic bronchoscope should be considered. Although two of our three patients had facial dysmorphism, the deformities were judged to be mild. There was no difficulty in airway management or in tracheal intubation.

Since respiratory failure is the most frequent cause of death [3–6], prevention of pulmonary complications in the peri-operative period is crucial. If pre-operative examination reveals respiratory infection, it should be treated vigorously, and postponement of the surgery should be considered. If the pharyngeal reflex is impaired or lower oesophageal sphincter pressure is diminished pre-operatively, the risk of aspiration will be higher. Therefore, withholding oral intake for a longer period than usual and avoidance of oral premedication are advisable. Tracheal extubation should be accomplished after the child is fully awake and responsive.

Cunliffe and Burrows [10] suggest that muscle relaxants be avoided in patients with musclar dystrophy because of the risk of an abnormal response. Heard and Kaplan [11], however, have reported a normal response to pancuronium in a patient who had an abnormal resistance to suxamethonium. Although muscle relaxants may not be needed because of muscle weakness, we believe that they should be administered in cardiac surgery with high-dose fentanyl anaesthesia, to control rigidity, to facilitate intubation and to prevent movements. All three patients received pancuronium, but no apparent complications associated with musclar relaxants were noted.

Heart rate decreased in all of the patients during laryngoscopy. Bradycardia can be caused by hypoxia, vagal stimulation due to tracheal intubation or by a pharmacological effect. Hypoxia was unlikely in these patients, because the lungs were well ventilated with oxygen, and the pulse oximeter continued to indicate an oxygen saturation of 99%. We speculate that the bradycardia was due to mechanical and pharmacological vagal stimulation, because: (1) all three patients showed bradycardia during tracheal intubation, and (2) in case 2, bradycardia occurred with mouth opening only after administration of fentanyl, diazepam, and pancuronium.

Several studies on the haemodynamic effects of fentanyl in children have been published [12–14]. These studies have shown that the heart rate decreases slightly after the intravenous injection of fentanyl, but does not fall further with tracheal intubation. The combination of diazepam and fentanyl is known to decrease myocardial contractility in adults; however, pancuronium is known to reverse the decrease in heart rate caused by fentanyl. Although the pharmacological effect on heart rate by a combination of these drugs is unpredictable, we feel that patients with nemaline myopathy have a higher incidence of bradycardia. Therefore, we assume that patients with nemaline myopathy are sensitive to vagal stimulation. Since the cardiac output of infants or small children depends primarily on the heart rate, atropine should be readily available.

Malignant hyperthermia (MH) has been associated with congenital myopathies such as central core disease [15] and Duchenne muscular dystrophy [16], but no reports have documented MH in patients with nemaline myopathy. Clinical and morphological similarities exist between nemaline myopathy and central core disease, and several patients with the histological features of both nemaline myopathy and central core disease have been reported [17–19]. Some authors even suggest that nemaline myopathy and central core disease are related or may actually be different manifestations of the same disease [17]. Therefore, patients with nemaline myopathy may have a predisposition to develop MH.

As mentioned above, patients with nemaline myopathy have many musculoskeletal deformities; similar deformities have also been noted in patients susceptible to MH. Some authors suggest that patients with such deformities have the possibility of malignant hyperthermal reaction [20, 21].

Serum CK and aldolase levels are usually normal in patients with nemaline myopathy, but a few cases of increased CK or aldolase have been reported [22, 23]. In cases 1 and 2, serum CK and aldolase levels were elevated. Although an elevated CK is unreliable as a predictor of MH susceptibility, we believe that it is prudent to regard patients with nemaline myopathy as having increased susceptibility to MH and avoid administering agents known to trigger MH.

In summary, we have reported the management of anaesthesia for cardiac surgery in three patients with nemaline myopathy. Our experience suggests that patients with nemaline myopathy seem to be vulnerable to noxious vagal reflex, and atropine should be readily available. Since respiratory complications in these patients are life-threatening, respiratory infections should be treated actively and extreme care should be exercised in the postoperative period.

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Anaesthesia, 1992, Volume 47, pages 409–410

CASE REPORT

Pulmonary vasoconstriction following intravenous nimodipine

A. T. LOVELL AND M. SMITH

Summary

A case is reported in which intravenous nimodipine therapy was associated with severe acute pulmonary hypertension in a patient with a subarachnoid haemorrhage. The patient had previously received enteral nimodipine without problems.

Key words

Calcium antagonists; nimodipine.
Complications; pulmonary vasoconstriction.

Case history

A morbidly obese 63-year-old Caucasian man, weighing 100 kg, was admitted with a spontaneous grade 2 subarachnoid haemorrhage. His past medical history was unremarkable apart from hypertension for which he took atenolol 100 $mg.day^{-1}$. He had a large alcohol intake and was a life-long heavy smoker. On admission his blood pressure was 200/100 mmHg. He was given nimodipine 60 mg every 4 h via a nasogastric tube and continuous monitoring of arterial and central venous pressures was started.

During the next 24 h he became increasingly hypoxaemic. A chest X ray confirmed the diagnosis of pulmonary oedema with right lower lobe pneumonia. This was treated by tracheal intubation and ventilation of the lungs. An oximetric thermodilution pulmonary artery (PA) catheter was inserted revealing a pulmonary artery wedge pressure (PAWP) of 30 mmHg and a shunt fraction of 35%. At this stage a fibreoptic intracranial pressure (ICP) monitor was inserted. His ICP remained normal throughout. Treatment was started with frusemide, intravenous nitrates and high dose ceftazidime. His lungs were ventilated with 5 cmH_2O positive end-expiratory pressure and within 4 h the PAWP and shunt fraction had fallen to normal. Over the next few hours he became progressively more septicaemic and required circulatory support, initially with dobutamine. Dopamine (18 $mg.h^{-1}$) was administered to maintain renal blood flow. However, his sepsis worsened and his systemic vascular resistance (SVR) fell further. Adrenaline was started in an attempt to maintain the SVR and the dobutamine was slowly withdrawn. Twelve hours later the patient stopped absorbing nasogastrically administered drugs and nimodipine was then given intravenously. At this stage his circulation was supported with 0.8 $mg.h^{-1}$ of adrenaline (Fig. 1).

Within minutes of starting the nimodipine infusion (1 $mg.h^{-1}$) PA systolic and mean pressures rose by 36% and PA diastolic pressure doubled. The PA pressure then continued to rise steadily reaching a maximum of 65 mmHg systolic after 3 h compared to the baseline of 32 mmHg. This was associated with a massive rise in right ventricular stroke work index (RVSWI) of 226%, although filling pressures and cardiac output remained unchanged (Fig. 2).

The systemic arterial pressure slowly decreased necessitating a 25% increase in the rate of adrenaline administration. There were no other significant haemodynamic or biochemical abnormalities (Table 1). The rises in PA pressure and RVSWI were maintained until it was possible to reintroduce enteral nimodipine therapy 60 h later.

Discussion

Nimodipine is a member of the dihydropyridine group of calcium antagonists, and has been advocated for the treatment of intracranial vasospasm after subarachnoid haemorrhage. Of the available calcium antagonists it shows the most specificity for cerebral vessels [1], although like other calcium antagonists it is also a systemic vasodilator.

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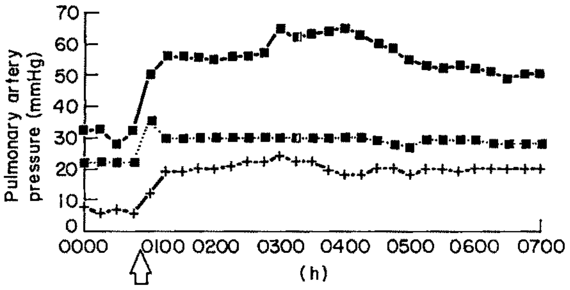

Fig. 1. Changes in pulmonary artery pressure following administration of intravenous nimodipine (represented by arrow).

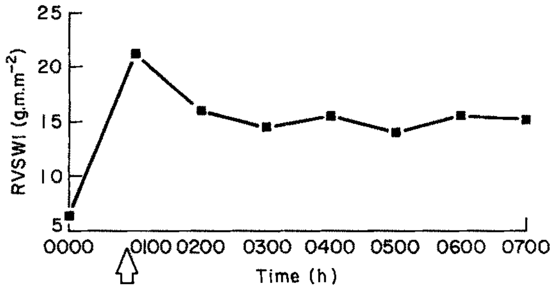

Fig. 2. Changes in RVSWI following administration of intravenous nimodipine (represented by arrow).

Nifedipine, a structurally similar drug, lowers PA pressures in patients with hypoxic pulmonary vasoconstriction [2,3]. Previous studies with nimodipine in man have shown either no change [4], or a small fall [5,6], in PA pressures. Some studies have also shown a fall in cardiac work indices [6] but these have been carried out in individuals not receiving inotropes.

The rise in PA pressure during nimodipine infusion in this patient must have been due to pulmonary vasoconstriction because it occurred without significant increase in cardiac output. The consequent rise in right ventricular afterload would then explain the sudden massive rise in RVSWI. The cause of the vasoconstriction is not clear although nimodipine must be implicated because of the temporal relationship between infusion of this drug and the observed changes in PA pressure. It is unclear why enteral therapy failed to have similar effects but this may be related to the site of delivery of the drug.

It is unlikely that nimodipine acted as a direct vasoconstrictor although this cannot be excluded. It is possible that nimodipine sensitised the pulmonary vessels to the alpha-agonist effects of adrenaline, although if this were the mechanism it is likely to have been noted previously because of the high levels of endogenous catecholamines after subarachnoid haemorrhage. It has been noted that the solvent used in the systemic preparation of nimodipine, a mixture of 20% ethanol and 17% polyethylene glycol, can cause a rise in pulmonary artery pressure in pigs (E. Pfenninger, personal communication), but this has not been reported in man. However, both these solvents are widely used in other drug formulations without apparent problems.

Pulmonary hypertension and an increase in pulmonary vascular resistance (PVR) has been reported in patients with severe sepsis [7] and this is associated with a high mortality. The mechanisms are poorly understood but may involve the action of vasoactive amines, endotoxin and angiotensin or deposition of microthrombi. However, as sepsis was well established before starting intravenous nimodipine and had not resolved prior to discontinuation of the infusion, this is unlikely to be the mechanism in our patient. Hypoxaemia and metabolic acidosis are also known to cause an increase in PVR but there were no changes in arterial or mixed venous oxygen tensions and ventilation remained unchanged throughout. The acid-base status and plasma electrolytes were also within normal limits during this episode.

Table 1. Haemodynamic effects following administration of intravenous nimodipine.

Time (h:min)	Systemic blood pressure (mmHg)	Caridac output (l.min^{-1})	PAWP (mmHg)	Nimodipine infusion (mg.h^{-1})
0000	146/68	12.3	12	0
0015	150/70	12.3	12	1.0
0115	155/60	13.5	12	1.0
0215	165/65	13.5	12	1.25
0315	160/65	13.5	12	1.5
0415	162/65	13.3	12	1.75
0515	152/65	13.0	12	2.0

Although the patient suffered no sequelae, severe acute pulmonary hypertension can rapidly be fatal due to right ventricular failure or pulmonary oedema. The aetiology of the elevation in PA pressure is unclear in our patient but we recommend care in the use of intravenous nimodipine in patients concurrently receiving inotropes.

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Anaesthesia, 1992, Volume 47, pages 411–413

CASE REPORT

Pulmonary collapse during anaesthesia in children with respiratory tract symptoms

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Summary

A frequent dilemma facing the anaesthetist is the child with respiratory tract symptoms. The risks of anaesthesia and surgery in these patients have not been clearly established. We present three cases which illustrate a potentially serious complication which may arise. Our patients each had symptoms of cough, but were systemically healthy. Two of the children had absent clinical signs, whilst the third had a normal chest X ray. However, during surgery and anaesthesia each child developed significant pulmonary collapse, associated with desaturation on oximetry.

Key words

Anaesthesia; paediatric.
Complications; respiratory.

Respiratory tract symptoms of runny nose, sore throat, congestion, mild malaise, fever, sneeze or cough are a common occurrence in children presenting for routine surgery. The aetiology of symptoms is commonly infective, however at present there are no universally accepted criteria for the diagnosis of infection, as opposed to other conditions such as allergy. Infection itself forms a spectrum of illness ranging from the mildest coryzal symptoms to lower respiratory infection with fever, malaise and productive cough. Differentiation of upper and lower respiratory symptoms is not always straightforward. A cough may result from bronchitis or from a postnasal drip. This makes discussion of the interaction of respiratory symptoms, anaesthesia and postoperative complications difficult [1].

The problem that faces the anaesthetist is whether the risks of anaesthesia in each case outweigh the inconvenience of postponement of the surgery. We report three patients who presented for surgery at our hospital. Each child had a pre-operative history of respiratory symptoms, and developed evidence of pulmonary collapse after the induction of anaesthesia.

Case histories

Case 1

A 6-year-old girl was admitted for tonsillectomy. She had a 6-month history of persistent cough with frequent bouts of tonsillitis. Her parents described her current condition as being typical, and in view of normal breath sounds and absence of pyrexia, it was decided to proceed with surgery. Anaesthesia was induced with thiopentone and suxamethonium, and the trachea was intubated with a RAE plain 5.5 mm tube. There was a large leak and an expiratory wheeze was present on the right side, despite careful positioning of the tube. The tube was changed for a 6.0 mm size, and auscultation revealed satisfactory air entry to both sides of the chest.

Anaesthesia proceeded, using spontaneous ventilation with oxygen, nitrous oxide and enflurane. Oxygen saturation was noted to be lower than expected at 90–93% despite an $F\text{io}_2$ of 0.5, and clinically satisfactory ventilation. At the end of the operation it was possible to re-examine the chest closely with the patient still anaesthetised. There was now clinical evidence of collapse of the right lung, with reduced respiratory movements, decreased air entry with bronchial breathing and dullness to percussion. A chest X ray was arranged (Fig. 1). This confirmed the diagnosis, showing right middle and upper lobe collapse, and verified correct tracheal tube position. With the patient still anaesthetised, physiotherapy with 'bagging' and suction was performed. This produced tenacious white sputum from which no organisms could be cultured. There was marked improvement of the clinical signs and oxygen saturation; anaesthesia was discontinued and the trachea extubated.

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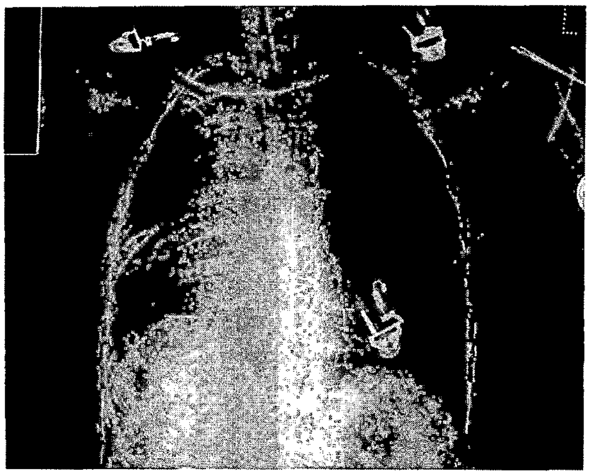

Fig. 1. Chest X ray of Case 1, taken before physiotherapy with the patient anaesthetised, showing right middle and upper lobe collapse.

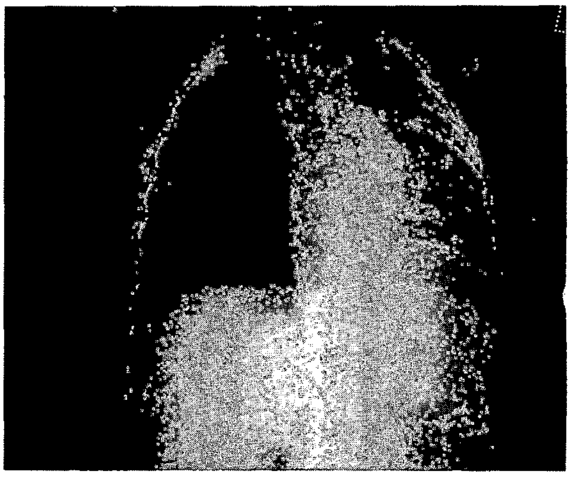

Fig. 2. Chest X ray of Case 3, showing left lung collapse after induction of anaesthesia.

A chest X ray 6 h later revealed some persistent right middle lobe collapse. In view of this and a mild pyrexia, therapy was commenced with erythromycin, and further physiotherapy arranged, prior to discharge home. Five days after her operation she was readmitted for further physiotherapy because of a refractory cough and continuing X ray evidence of right middle and lower lobe collapse; with this treatment she made a swift recovery.

Case 2

A 2.5-year-old girl was admitted following a 2-week history of diarrhoea and vomiting, with the more recent onset of unproductive cough and runny nose. Clinically she had reduced air entry with crackles and dullness to percussion over the right middle zone. Chest X ray was normal. Because of the history of abdominal symptoms and a barium enema suggestive of Crohn's disease, the admitting surgeon wished to perform urgent colonoscopy. A general anaesthetic was planned for this procedure.

Anaesthesia was induced with atropine, thiopentone and suxamethonium, and the trachea intubated with a plain 4.0 mm tube. A small leak was apparent. A pharyngeal pack was inserted, and alfentanil and atracurium given. Anaesthesia was maintained with oxygen, nitrous oxide and isoflurane, with IPPV. It was noted as the operation proceeded that oxygen saturation fell to 94%. Tube position was checked by auscultation, and found to be correct. Copious secretions were obtained on tracheal suction prior to extubation. There was no evidence at any time of regurgitation of stomach contents.

A postoperative chest X ray showed bilateral upper lobe shadowing and collapse at the right base. Over the next 3 days, the child was given chest physiotherapy and had no further problems. There was no growth on culture of sputum, and antibiotics were not necessary.

Case 3

A 14 kg, 3-year-old boy was admitted for clearance of metastatic rhabdomyosarcoma from his left groin and popliteal fossa. At pre-operative assessment he was noted to have had a runny nose and a mild cough for 2 weeks. In view of the absence of pyrexia and a clear chest on auscultation, it was decided to proceed with surgery.

After trimeprazine premedication, anaesthesia was induced with atropine, thiopentone, alfentanil and atracurium. The trachea was intubated with an armoured uncuffed 5.0 mm tube. It was noted almost immediately that the oxygen saturation was 92% and that there was reduced air entry to the left side of the chest. The position of the tracheal tube was checked carefully, and a chest X ray performed (Fig. 2). This showed left lung collapse. Physiotherapy was carried out with the patient still anaesthetised, but because of the magnitude of the proposed operation, it was decided at this point to postpone surgery, and to re-schedule it for a later date.

Sputum sent for culture did not produce organisms, and a postoperative chest X ray showed improvement of the pulmonary collapse. Anaesthesia and surgery proceeded uneventfully one month later.

Discussion

Respiratory symptoms in a child presenting for surgery may be due to allergy or to differing severity of infection. Allergy usually produces chronic symptoms which may show some seasonal variation. Children with allergies are affected by a spectrum of symptoms ranging from rhinitis to severe reversible bronchospasm. These children often present to the ENT surgeons with a history of recurrent otitis media and require myringotomy or adenotonsillectomy. Children with allergy may suffer concurrent respiratory infection. Infection is most commonly viral in origin, and occurs frequently in childhood. A young child may have three to eight such illnesses annually [2]. Fennelly and Hall [3] draw attention to diagnostic difficulties in upper respiratory tract infection, due to variation in symptoms between individuals. Rhinoviruses, myxoviruses and respiratory syncytial virus are the most commonly incriminated pathogens, and these are difficult to isolate. This makes pre-operative assessment of the patient less than straightforward. It is important, nevertheless, for the anaesthetist to assess the relative risk of anaesthesia in each case. Consideration should be given to postponement, although the justification for doing so may appear tenuous.

Large retrospective studies have sought to establish complication rates. In one [4], anaesthetic records of 29 220 paediatric cases showed respiratory symptoms in 10.5% prior to operation: 5.9% had upper respiratory illness or difficult airway, and 4.6% had lower respiratory symptoms including asthma and cystic fibrosis. Intra-operatively, 2.35% developed airway obstruction, laryngospasm, bronchospasm or other respiratory problems. In the recovery room 6.09% developed these problems, whilst within the first 3 days postoperatively, 3.28% developed croup, atelectasis, pulmonary oedema or pneumonia. Unfortunately, due to the method of data collection, variables were grouped together (for example upper respiratory illness and difficult airway) and no attempt could be made to relate pre-operative condition to outcome. In another survey [5], anaesthetic records of 3585 children were reviewed. Respiratory symptoms were present pre-operatively in 3.40%, whilst 3.71% were patients asymptomatic at the time of surgery but who had a history of upper respiratory symptoms within the preceding 2 weeks. The prevalence of respiratory complications in the healthy patients and in those with current symptoms were very similar, 1.61% and 1.64% respectively. However, the patients who had recently recovered from upper respiratory symptoms had a significantly elevated complication rate of 5.31%. The complications included laryngospasm, bronchospasm, stridor and breathholding. The increase in complications found in the group recovering from symptoms suggests that airway reactivity is heightened for some time after infection. This is in keeping with evidence of increased reactivity after upper respiratory tract infection [6], and with findings of altered pulmonary mechanics for up to 6 weeks following viral infection [7, 8]. A recent editorial gives a detailed review of work done on the pathophysiology of viral airway infection [9].

Our three cases had symptoms involving the respiratory tract pre-operatively. Two of the patients had a cough which, in the absence of clinical signs, was considered inadequate grounds for cancellation of surgery. The third had a normal chest X ray. Pulmonary collapse occurred as a complication in each child, and its detection was aided by pulse oximetry. It is likely that Case 1, with her history of chronic cough, was suffering upper respiratory tract infections associated with recurrent tonsillitis. It is questionable whether her condition could have been improved, and it was felt that the best treatment was the tonsillectomy itself. Case 2 was undergoing urgent investigative surgery, and Case 3 had a malignancy making postponement of surgery undesirable. Fortunately all three cases made a full recovery although Case 1 had to be readmitted to hospital to receive further physiotherapy before making a full recovery.

Pulmonary collapse is an unusual but serious complication if unrecognised, with the risk of hypoxia, which was evident in our patients. One study [10] found that children with signs and symptoms of upper respiratory infection had a significantly increased frequency of recovery room desaturation to below 95%. Of our patients, only Case 2 had a pre-operative chest X ray, and this was normal, despite clinical signs. The other two patients were clinically normal, and therefore X ray examination was not requested.

Obviously, to postpone every child with upper respiratory tract symptoms is not feasible. There is the difficulty of diagnosis and opinions on the risks of anaesthesia vary. Some work suggests that complication rates are not increased [5], whilst other surveys give results that conflict with this [11]. The duration of proposed surgery and the method of anaesthesia are of importance, and may influence decision making. Interestingly the patients recovering from upper respiratory infection in the survey above [5], underwent shorter procedures than those who were well or currently affected. The reason for this may be that surgery in patients in whom longer procedures were planned was more likely to be postponed. Recent work has shown that children undergoing anaesthesia necessitating tracheal intubation have a significantly increased risk of pulmonary complications [11]. The tracheal tube could spread infection or mucus to the lower respiratory tract, causing mucus plugging, especially if positive pressure ventilation is employed. We believe that these factors were important in our cases.

We feel that our three patients illustrate an important point. Major pulmonary collapse developed despite normal X ray and absence of pre-operative clinical signs. Each child was well, apart from a cough and mild runny nose. Tracheal intubation and positive pressure ventilation may have helped cause mucus plugging. Thus the duration and nature of the procedure should influence the anaesthetist's decision regarding postponement. Pre-operative history must be heeded; an apparently well child may develop serious complications. Careful consideration should be given to postponement of surgery. If surgery cannot be postponed, close monitoring of oxygen saturation by oximetry is essential, as this should result in the early detection of complications such as those outlined above.

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Anaesthesia, 1992, Volume 47, pages 414–420

APPARATUS

A comparison of the filtration properties of heat and moisture exchangers

R. M. HEDLEY AND J. ALLT-GRAHAM

Summary

Heat and Moisture Exchangers are used increasingly as filters to prevent the contamination of breathing apparatus and to limit cross-infection. A series of laboratory tests has been developed to evaluate the microbial filtration and air flow resistance properties of these devices. The tests were designed to simulate the clinical situation and therefore evaluated devices in both dry and wet conditions. The devices tested (Engstrom Edith, Pall BB50T, Dar Hygrobac, Intersurgical Filtatherm and Intersurgical Filtaguard) were each representative of a particular type of construction. The simple hygroscopic device (Engstrom Edith) showed poor airborne and liquid-borne filtration efficiency, but its resistance to air flow remained low in all conditions. The composite devices (Dar Hygrobac, Intersurgical Filtatherm and Intersurgical Filtaguard), which all possessed relatively large pores, performed well in terms of dry airborne filtration efficiency, but showed substantial increases in air flow resistance and poor filtration efficiency in the presence of liquid. The pleated membrane filter (Pall BB50T), which possessed small pores, showed good airborne filtration efficiency and prevented the passage of liquid. The latter property enabled this device to prevent the passage of liquid-borne contamination and to maintain a low resistance to air flow in wet conditions. It would appear that in terms of contamination control and air flow resistance the pleated membrane filter provides a wider margin of safety than either the hygroscopic or composite devices.

Key words

Equipment; heat and moisture exchangers, bacterial filters.

Disposable heat and moisture exchangers (HMEs) have established themselves as convenient and efficient devices for maintaining a humid environment in the upper airway of patients whose tracheas are intubated [1–8]. They are used increasingly as filters to prevent contamination of breathing apparatus [9] and to limit cross-infection, particularly in the setting of intensive care [10–12]. Currently there are no standards for 'patient-end' filtration devices and there is little information upon which decisions the suitability of various devices can be based. The need for standards is of importance because sepsis, multi-organ failure and viral contamination account for considerable morbidity and mortality.

The ideal filter for use in the intensive care unit and operating theatre should protect apparatus from contamination with airborne bacteria and viruses, and should provide an effective barrier to liquids such as infected sputum or pulmonary oedema. These properties should be reliable with prolonged use. A filter should also be unaffected by nebulised drugs.

The devices which are available differ in their design features, but there is little information to guide the clinician as to their suitability in different clinical environments. Hygroscopic HMEs consist of wool, foam, or paper-like material, often coated with moisture-retaining chemicals such as calcium chloride or lithium chloride. They possess little resistance to gas flow because of their large pore size, but this may limit their filtration properties. In addition, excessive water retention may result in an increase in air flow resistance.

Composite filters consist of a hygroscopic layer and a large-pore felt filter layer. The felt is sometimes subjected to an electrical field to increase its polarity (an 'electret' felt). This process improves dry gas filtration efficiency and water repellance (hydrophobicity).

Pleated membrane filters consist of a pleated hydrophobic membrane with a large surface area and very small pores; this prevents the ingress of water droplets, ensuring that liquids do not pass through, and air flow resistance remains low even in wet conditions.

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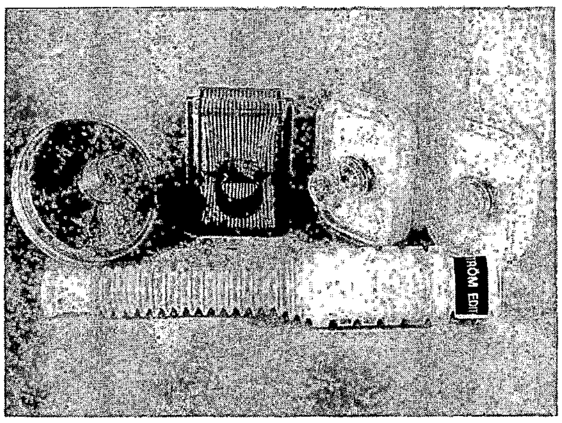

Fig. 1. Devices studied. Back, left to right: Dar Hygrobac, Pall BB50T, Intersurgical Filtatherm and Intersurgical Filtaguard. Front: Engstrom Edith.

The development of new materials has produced a new generation of HMEs with widely varying filtration properties [12] which may affect their performance in clinical practice. A series of simple laboratory tests was developed to measure resistance, hydrophobicity (including the retention of artificial saliva), filter efficiency with respect to both liquid and airborne bacterial challenges and the effect of nebulised drugs on air flow characteristics.

The following devices were studied: Dar Hygrobac, Pall BB50T, Intersurgical Filtatherm, Intersurgical Filtaguard and Engstrom Edith (Fig. 1). These represent a selection of devices ranging from the simple hygroscopic HME (Engstrom Edith) to composite devices (Filtatherm and Hygrobac) and the pleated membrane type (Pall BB50T). The Filtaguard is intended solely for use as a filter and the Engstrom Edith solely as an HME. The composite devices are marketed as combined HME filters. The Pall filter is indicated for use either as an HME filter at the 'patient-end' of the circuit or for use simply as a filter at the 'machine-end' of the circuit. The Filtaguard would not be expected to fulfil a role for which it is not designed, (an HME filter) but was included so that a discussion of the different properties could be made with reference to the different styles of construction.

Hydrophobicity and resistance to airflow

The purpose of this test was to compare hydrophobicity in each of the devices and to measure air flow resistance in the dry and wet states. In addition, the effect of simulated expiration on air flow resistance was evaluated to identify whether the effect of wetting the device was transient or not.

The resistance of each device was measured by connecting it to a compressed air supply and using a regulator to supply a flow of 60 $l.min^{-1}$. The pressure drop across the device was measured using a water manometer (Poddy Ltd). A volume of 15 ml of water was then instilled into the vertical device. If water passed through the device, this was noted. Air flow resistance was measured. A self-inflating reservoir bag (Ambu bag, Laerdal) was connected to the patient-side of the device and manually squeezed to deliver an artificial breath (800 ml over 3 s) through the device. A spirometer (Micro Medical Instruments) interposed between the bag and the device ensured that the tidal volume was constant. Air flow resistance was measured after one 'breath' delivered in this way and repeated after 15 'breaths'.

Simulated clinical hydrophobicity using artificial saliva

The surface tension of saliva is about two-thirds that of water. Thus, it is possible for a device to perform well on the hydrophobicity test but not to offer adequate protection from contaminated secretions. An artificial patient was constructed from a 2l rubber reservoir bag (Waters) connected to a Bennett Cascade Mk II (Puritan Bennett) humidifier (Fig. 2). The reservoir bag was 'ventilated' using a Servo 900C ventilator (Siemens Elema AB). The device under test was fitted at the 'patient-end' of the system between the artificial patient and the catheter mount. Six

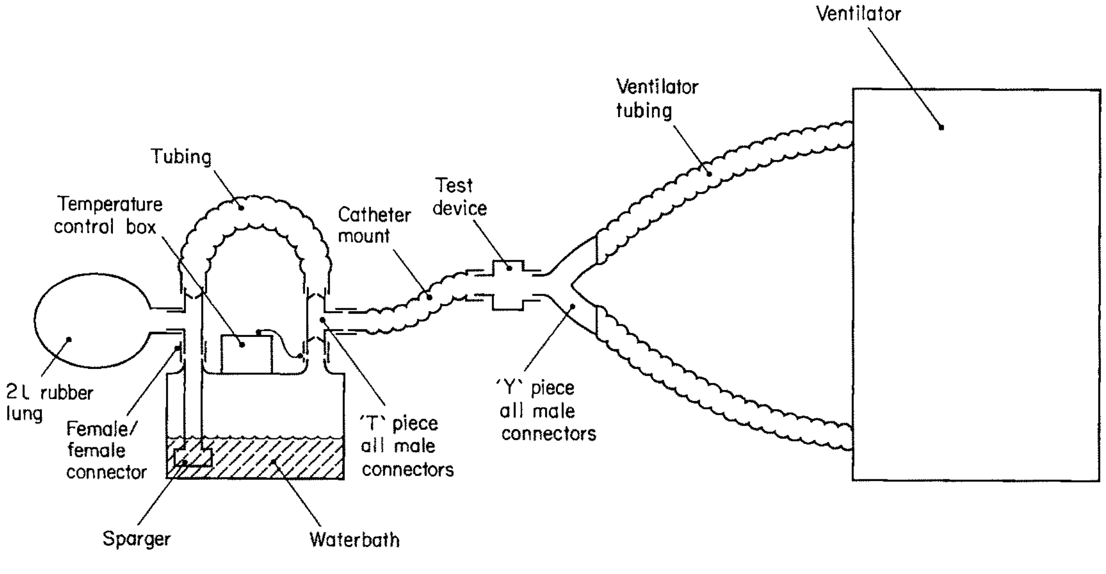

Fig. 2. Artificial patient test rig used to assess the clinical hydrophobicity of devices with artificial saliva. With the addition of a drug nebuliser between the test device and catheter mount the same test rig was used to simulate drug nebulisation in order to assess device resistance under such conditions.

millilitres of artificial saliva (British National Formulary) were deposited on the patient side of the device. The device was reconnected and observed closely during the running of the apparatus. If saliva was observed to penetrate through the device within 24 h the time was noted, and the ventilator was stopped.

Liquid bacterial challenge

The purpose of this experiment was to investigate the liquid-borne bacterial removal properties of devices. A bacterial suspension of *Pseudomonas diminuta* (NCIB 11091) in water (approximately 10^6 colony forming units [CFU].ml^{-1}) was prepared. A volume of 100 ml of this bacterial suspension was introduced into a sterile 15 cm length of 22 mm ventilator tubing connected vertically to the device under test. If liquid passed through the device it was collected in a sterile glass beaker. Viable counts were performed on the effluents collected. The number of CFUs were counted on tryptone soya agar plates after 24 and 48 h and the number of CFU per millilitre of fluid calculated for both influent and effluent samples.

The reduction in bacterial titre for each device was calculated using the formula:

$$\text{Titre reduction (TR)} = \frac{\text{Bacterial challenge (volume filtered} \times \text{CFU.ml}^{-1})}{\text{Bacterial recovery (effluent volume} \times \text{CFU.ml}^{-1})}$$

The efficiency of each device was calculated using the formula:

$$\%\text{Efficiency} = 100 - \left[\frac{\text{Bacterial recovery (effluent volume} \times \text{CFU.ml}^{-1})}{\text{Bacterial challenge (volume filtered} \times \text{CFU.ml}^{-1})} \times 100\right]$$

$$\text{or}\left[1 - \frac{1}{\text{TR}}\right] \times 100$$

Airborne bacterial challenge

This method was designed to challenge devices with monodispersed airborne bacteria. The bacterium *Pseudomonas diminuta* (NCIB 11091) was used because of its robustness and extremely small size (0.3–2.0 μm). As it is smaller than many of the common bacterial pathogens it represents a stringent test of filter efficiency. The aerosol challenge apparatus [11] is designed to allow large droplets leaving the nebuliser (typically 2 μm) to evaporate to dryness before reaching the test device. This ensures that the device is challenged with a dry monodispersed suspension of bacteria.

The apparatus (Fig. 3) consisted of a De Vilbiss model 40 nebuliser connected to a stainless steel test rig which had been sterilised by autoclaving. The test device was connected aseptically to the other end of the rig. Bacteria that passed through the test device were collected in an all glass liquid impingement sampler (A.W. Dixon) containing sterile water. Air was drawn through the apparatus by applying a vacuum downstream of a 3001 FRP filter (Pall Europe Ltd) which ensured sterility. The flow of gas through the apparatus was maintained at 28 l.min^{-1}. The experiment was conducted using five samples of each device for a test time of 15 min. At the end of this period the volume of liquid remaining in the nebuliser was measured,

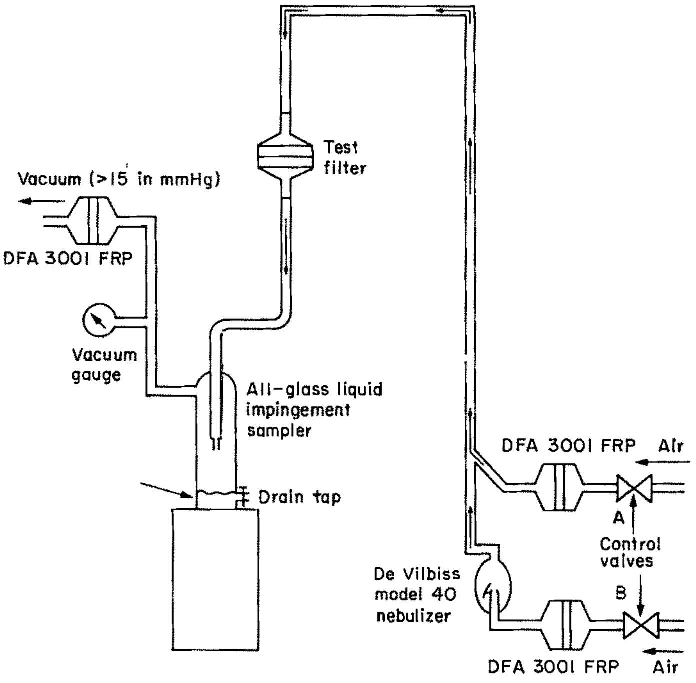

Fig. 3. Airborne bacterial challenge test rig.

and serially diluted before being cultured on tryptone soya agar plates. This process was repeated with the liquid in the impingement sampler.

The efficiency of the system was established by running control experiments without a test device and determining the number of viable bacteria remaining once they had passed through the apparatus. This represented the aerosol challenge to the device.

The rig efficiency was calculated using the following equation:

$$\text{Rig efficiency (\%)} = \left[\frac{\text{Total number of bacteria recovered}}{\text{Final nebulised titre (CFU.ml}^{-1} \times \text{ml nebulised)}}\right]$$

The bacterial challenge to each device was then calculated using the formula:

$$\text{Total challenge} = \text{ml nebulised} \times \text{nebuliser challenge titre} \times \text{rig efficiency}$$

The filter titre reduction (TR) for each test device could then be calculated from:

$$\text{TR} = \frac{\text{Total challenge}}{\text{Total number of bacteria recovered}}$$

Therefore for each test the percentage efficiency of the device was calculated from the formula:

$$\text{Filter efficiency (\%)} = \left[1 - \frac{1}{\text{TR}}\right] \times 100$$

Resistance to airflow following drug nebulisation

Previous work has shown that nebulised drugs can alter the characteristics of devices. Drugs may modify device media, allowing water to penetrate and cause increased resistance to airflow. Salbutamol was chosen for investigation in this study as this drug is in widespread use.

The experiment used the artificial patient described in the simulated clinical hydrophobicity test. The device under test was fitted at the 'patient end' of the system, with the nebuliser connected between the catheter mount and the device.

The differential pressure across the device at an airflow rate of 60 l.min^{-1} was measured for each device at the start of the test. The measurement was repeated after exposure to 2 ml of salbutamol 5 mg.ml^{-1} solution (Allen and Hanburys) mixed with 2 ml saline 0.9%. Each device was tested with four drug nebulisations given 2-hourly.

Results

Table 1 shows the air flow resistance and hydrophobicity of each device. The Pall BB50T was the only device that did not allow water to penetrate into the media at any stage. As soon as water was introduced into the Engstrom Edith device it passed through. After the first simulated breath, water began to ingress into the Hygrobac, Filtatherm and Filtaguard devices, and this was associated with a significant increase in resistance. These increases in resistance were unaffected by simulated breathing through the device. The draft International Standard for heat and moisture exchangers (ISO/DIS 9360.2) requires a pressure drop across the HME not exceeding 5 cmH$_2$O at a flow of 1 l.s^{-1}. The increases in resistance shown by the Hygrobac, Filtatherm and Filtaguard devices exceeded this draft International Standard when wet.

Table 2 shows the results of the simulated clinical hydrophobicity test. Artificial saliva did not pass through the Pall BB50T and Hygrobac devices, although it did penetrate into the sponge of the Hygrobac device. The mean time for passage of saliva through the remaining devices was 38 min for the Edith, 27 min for the Filtatherm and 22 min for the Filtaguard.

Table 3 shows the results for the liquid-borne bacterial challenge test. Since the Pall BB50T did not allow water to pass through, an efficiency of 100% was recorded. Water flowed freely through all the other devices. It passed through the Edith device as soon as the bacterial suspension was introduced and started to pass through the Filtaguard and Filtatherm after 5 s and the Hygrobac after 10 s.

The Hygrobac, Filtatherm, Filtaguard and Edith devices showed variable degrees of efficiency. However, in terms of numbers of bacteria allowed through by these devices, none possessed any useful bacterial retaining property.

Table 1. Differential pressures (mmH$_2$O) across devices at 60 l.min^{-1} air flow after a challenge of 15 ml of water followed by 15 simulated exhalations.

	Edith	Pall BB50T	Hygrobac	Filtatherm	Filtaguard
Before test	17.0	11.0	13.5	22.0	16.5
After challenge with 15 ml water	21.0	21.0	52.0	> 60.0	> 60.0
After one exhalation	17.5	21.0	51.0	> 60.0	> 60.0
After 15 exhalations	21.5	23.0	> 60.0	> 60.0	> 60.0
Passage of water through device	Yes*	No	No†	Yes‡	Yes‡

*Water passage occurred immediately after it was introduced into the device.
†Water soaked into the sponge material immediately after it was introduced into the device.
‡Water penetrated into the media after the first simulated exhalation.

Table 2. Time (min) for artificial saliva (6 ml) to pass through devices in a simulated ventilated patient model (V_T666 ml, frequency 15 breath.min^{-1}).

Experiment	Edith	Pall BB50T	Hygrobac	Filtatherm	Filtaguard
1	41			30	31
2	37	No passage	No* passage	32	26
3	33			28	17
4	40			27	14
5	—			21	14

*Artificial saliva soaked into sponge material.

Table 3. Filtration efficiencies (%) with a liquid-borne bacterial challenge (10^8 *Ps. diminuta.* in 100 ml water).

Experiment	Edith	Pall BB50T	Hygrobac	Filtatherm	Filtaguard
1	0	100*	59	54	0
2	2.1	100*	47	52	61
3	42	100*	53	75	65
4	65	100*	25	63	40
5	68	100*	21	66	0

*Liquid did not pass through the device.

Table 4. Filtration efficiencies (%) with an airborne bacterial challenge (10^8 monodispersed *Ps. diminuta*).

Experiment	Edith	Pall BB50T	Hygrobac	Filtatherm	Filtaguard
1	6.8	99.9999	99.98	99.9999	99.9998
2	35	99.9996	99.95	99.9993	99.994
3	63	99.9999	99.987	99.9999	99.9997
4	6	99.9991	99.96	99.9997	99.9993
5	40	99.9995	99.98	99.98	99.9986

Table 5. Differential pressures (mmH_2O) across devices at 60 l.min^{-1} air flow following sequential nebulisations of salbutamol (10 mg in 4 ml) in a simulated patient model.

Nebulisation	Pall BB50T	Hygrobac	Filtatherm	Filtaguard
0	10.0	9.5	16.25	14.0
1	13.25	12.25	31.0	18.0
2	14.0	12.5	26.5	18.25
3	15.5	13.0	21.75	17.5
4	16.5	13.25	20.75	18.75

Table 4 shows the results of the airborne bacterial challenge tests. The Edith HME is not marketed as a filter and its performance in this test was poor. The Pall BB50T, Filtatherm, and Filtaguard all performed well, achieving efficiencies of 99.9996% for the Pall BB50T 99.9977% for the Filtatherm, and 99.9984% for the Filtaguard. The Hygrobac device performed less well, attaining an average efficiency of 99.97%.

Table 5 shows the airflow resistance of each device after drug nebulisation. None of the devices showed any clinically significant increase in resistance.

Discussion

These experiments highlight some of the differences between devices in respect of the features which influence their filtration properties. These features comprised pore size, hydrophobicity, membrane thickness, surface area, and geometry.

The simple HME (Engstrom Edith) presented essentially no barrier to contaminating substances. The ability of the more complex filters to resist organisms is achieved by their tight meshwork of fibres. The airborne bacterial challenge exemplified this point. The composite and pleated membrane filters all did well when faced with a challenge of dry monodispersed airborne bacteria. Viruses and the smaller bacteria undergo Brownian motion such that the sphere or zone occupied by a single organism is much larger than the organism itself. Therefore an effective microbial gas filter does not need to have pores which are smaller than the size of a virus; particles which are diffusing randomly are trapped easily in a thick interwoven mesh.

Product information often quotes bacterial and viral removal efficiency data from the results of various types of aerosol challenge tests. However, performance may be different under 'wet' conditions. The hydrophobicity tests showed a dramatic difference between composite and pleated-membrane filters. These results supplement

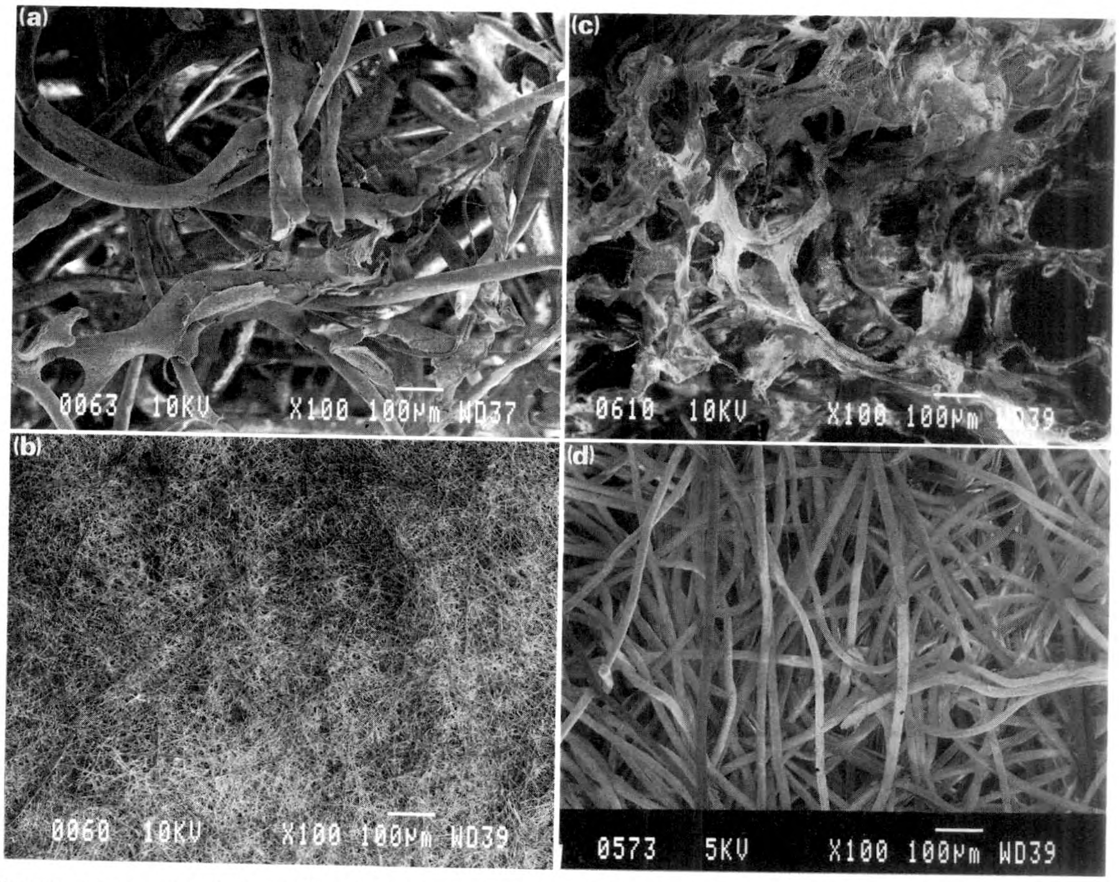
(a)
0063 10KV X100 100µm WD37
(c)
0610 10KV X100 100µm WD39
(b)
0060 10KV X100 100µm WD39
(d)
0573 5KV X100 100µm WD39

Fig. 4. Electron micrographs of the media of devices. (a) Engstrom Edith, (b) Pall BB50T, (c) Dar Hygrobac and (d) Intersurgical Filtatherm. Note photographs are all at the same magnification.

previous studies [12,13]. Filters which allowed water to pass through them also allowed the passage of micro-organisms. In other words, in contrast to the airborne bacterial test, the water acted as a medium or vehicle for transporting bacteria across the filter material. The term 'hydrophobicity' therefore requires elaboration. The pleated-membrane filter was watertight and 'saliva-proof' whereas the composite filters demonstrated only a relative hydrophobicity. These results can be explained by considering the pore sizes of the different devices. Figure 4 shows that, in relative terms, the simple hygroscopic HME and the composite filters had large pores whereas the pleated membrane type filter possessed small pores. Although the material of the composite filters was hydrophobic, the devices were not watertight because the pores were too large to prevent water ingression into, and passage through, the filter material. This property of liquid retention appears to be of paramount importance if a filter is to remain an effective barrier to infected secretions.

The degree of hydrophobicity has implications not only for contamination control, but also for safety. A recent report [14] described the saturation of a hygroscopic HME with blood, resulting in an increase in airway resistance and increased difficulty in ventilating the lungs. The extent to which air flow resistance increased in the composite devices is worrying. It may be argued that if large pores allow water to pass through, then there is little likelihood of the filter becoming blocked. This certainly seemed true for the Edith HME, but did not apply to the composite filters. When these devices became wet, airflow resistance increased dramatically to levels in excess of the draft International Standard, suggesting that these devices may be unsafe in such conditions. In contrast, the small pore-size and non-wettable nature of the thin membrane filter ensured that surface tension effects prevented water from penetrating the pores of this device and its resistance to airflow remained low.

The results of the drug nebulisation test are difficult to interpret. The problem of increases in airflow resistance following drug administration was reported originally in relation to ipratropium bromide; benzalkonium chloride, used in the formulation as a preservative, was found to modify the surface of filters and compromise their hydrophobicity. However, this applied only to filters fitted on the expiratory port of ventilators when a heated waterbath humidifier was in use. Ipratropium has been reformulated and the same problem has not been described for salbutamol. More recently, there have been reports [15] of the sudden obstruction of a composite device (Hygrobac) when used at the patient-end in conjunction with nebulised drugs. In the present study, the devices most affected by drug nebulisation in terms of air flow resistance were the Filtatherm and Hygrobac. It is possible that this effect was due entirely to accumulation of water in the hygroscopic element; this would explain why the Filtaguard was much less affected. The effect of drug nebulisation on filtration efficiency was not assessed in this study. This is an important factor as filters are often used during drug nebulisation to protect the sensitive pressure transducers in the expiratory blocks of some ventilators.

The geometry of a device is significantly affected by the pore size of the filter medium. A large-pore material has a low air flow resistance when dry, but in order to achieve adequate airborne filtration efficiency, it must have significant depth. Consequently, it is constructed as a thick, flat layer. In contrast, a small-pore membrane achieves high filtration efficiency without the necessity for significant depth. In order to achieve low air flow resistance, a very large surface area of membrane can be pleated so that it can be placed in a low-volume housing.

The differences in geometry between small-pore and large-pore devices contributes to the differences in their performance with regard to air flow resistance in the presence of liquid. The thick, flat layer of large-pore devices allows entrained fluid to spread into the surface of the material. Because the pore size is large, the gas flow forces liquid into the depth of the material, thus obstructing gas flow. In contrast, the pleated membrane has small pores which prevent the ingression of water; water runs off the surface, leaving the pores open. Water is held back, and air flow is maintained due to the very large surface area provided by pleating. The large pore size of the composite filters explains why the potential for blockage is greater. This has safety implications. For example, a patient who undergoes surgery in the prone position may be at risk if such a filter is hanging down and collecting secretions.

It appears that thin pleated membrane filters have a wider margin of safety than either hygroscopic HMEs or composite devices in terms of contamination control and air flow resistance.

Acknowledgment

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APPARATUS

High frequency jet ventilation for microlaryngeal laser surgery

An improved technique

S. S. DHARA AND P. J. BUTLER

Summary

The use of a triple lumen central venous catheter, which can be shielded from laser irradiation by metal tape, as a conduit for high frequency jet ventilation in six children, is described. The problems of anaesthesia for laryngeal laser surgery and the advantages of the technique described in this paper are discussed.

Key words

Surgery; laryngeal, laser.
Ventilation; high frequency jet.

The administration of anaesthesia for laser surgery of the larynx entails competition with the surgeon for access to the airway and provision of a clear, immobile field in an atmosphere that does not encourage combustion [1,2]. High frequency jet ventilation (HFJV) may be a useful technique but has the potential hazard of barotrauma [3]. In this paper a method of surmounting some of the problems is described and its application in the anaesthetic management of six patients aged 6 months to 10 years is presented.

Case histories

Four male patients aged 6 months, 2 years, 9 years and 10 years were referred to the otorhinolaryngeal surgeons with stridor of gradual onset and were scheduled for direct laryngoscopy under anaesthesia. The two older children had a history of laser surgery to laryngeal papillomata on previous admissions whereas the other two patients had no past medical history. Apart from stridor, all four were without abnormality on clinical examination and routine blood test screening.

The older patients were premedicated with trimeprazine syrup 3 $mg.kg^{-1}$ and the infant received no premedication. Anaesthesia was induced either with a sleep dose of propofol or by inhalation of up to 4% halothane in oxygen. Direct laryngoscopy then confirmed the presence of laryngeal papillomata in all four patients. The glottis was sprayed with 4% lignocaine and, after atracurium was given for neuromuscular blockade, a 7 French gauge triple lumen, central venous catheter (Certofix Trio, B. Braun, Melsungen A.G.) was introduced into the trachea. The catheter had been longitudinally wrapped in a single layer of reflective foil tape, except for the distal segment that would be positioned below the operative site. HFJV was instituted via the distal channel of the catheter using an Impulse ventilator (model 303, Healthdyne) at a frequency of 80 to 100 min^{-1}. The middle lumen of the catheter was connected to the airway pressure measurement port of the ventilator, so that either mean or peak pressure could be monitored continuously (Fig. 1). The driving pressure used was 66 kPa in the 6-month old and between 66 and 133 kPa in the others, depending on the size of the child, with an inspiratory to expiratory time ratio of 0.33. The air–oxygen mixture was adjusted to provide the lowest inspired oxygen fraction possible, whilst ensuring pulse oximetry readings of 95% or above (Oxicap 4700, Ohmeda). Anaesthesia was maintained with a propofol infusion at 6 to 8 $mg.kg^{-1}.h^{-1}$ with bolus doses of fentanyl and atracurium as needed. Electrocardiograph and blood pressure (Dinamap model 8100, Critikon) were monitored throughout the induction and maintenance of anaesthesia.

Throughout the procedures the cardiovascular parameters remained stable. There was easy access to all areas of the surgical field, since the surgeon could move the flexible catheter around. Occasionally the placement of saline-soaked swabs obstructed the passage of expired gas through the glottis, producing a rise in the mean airway pressure. When the 0.5 kPa threshold, preset by the anaesthetist, was reached the ventilator automatically stopped delivering gas. The surgeon was alerted to reposition the

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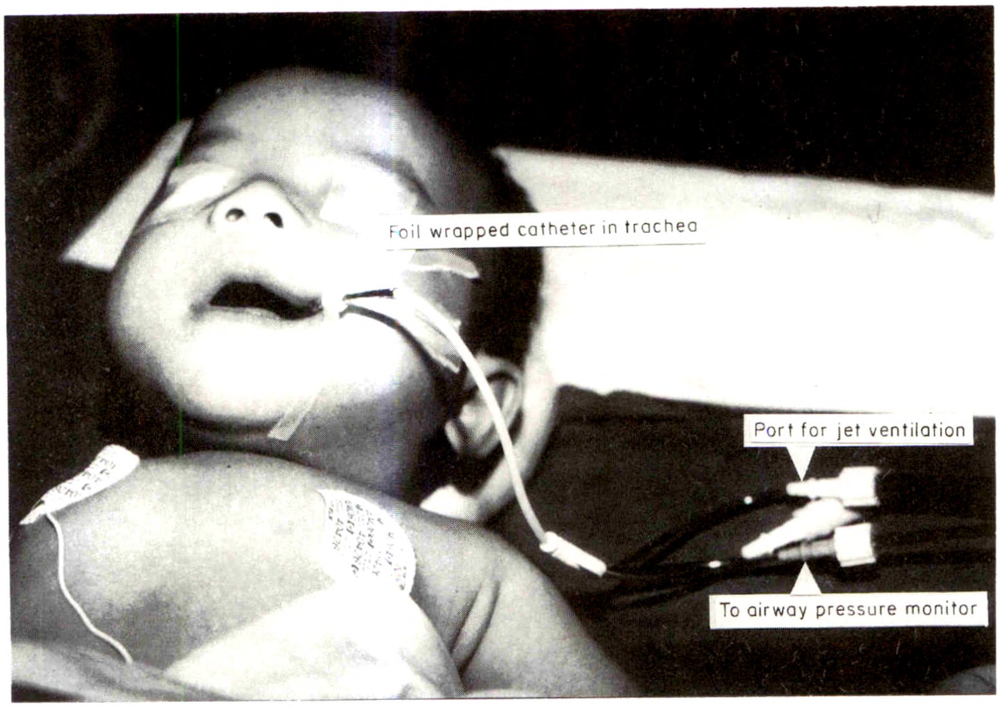

Fig. 1. Arrangement for high frequency jet ventilation through the triple lumen central venous pressure catheter, for performance of microlaryngeal laser surgery in an infant.

swabs, relieving the obstruction and allowing ventilation to continue.

In the two older patients, in whom a greater length of catheter could be inserted into the trachea, it was possible for the proximal lumen, which opens 4.3 cm from the tip, to be used to monitor the expired gases in the trachea. End-tidal carbon dioxide tension was monitored using an Oxicap (model 4700, Ohmeda) and ranged from 4.5 to 5.5 kPa. In the smaller patients the proximal lumen opened above the level of the vocal cords and was covered by the foil tape, rendering it unusable.

Peroperative inspection of the distal end of the catheter with a small bronchoscopic telescope (Storz) did not reveal the anticipated movement of the tip with each jet ventilation.

At the end of surgery the propofol infusion was stopped and neuromuscular blockade was reversed with neostigmine and atropine. HFJV was continued with 100% oxygen until recovery from anaesthesia was sufficient for extubation to be performed. Humidified oxygen was supplied via a facemask in the recovery room. In all four cases the surgery relieved the stridor and the postoperative hospital stays were uneventful. The same technique was used in two other patients.

Patient 5 was a 2-day-old infant with stridor from birth. An attempt at laryngoscopy and diagnosis at another hospital had been unsuccessful and the patient was transferred with a 3.0 mm oral tracheal tube in place, breathing spontaneously. After propofol induction and extubation, pharyngolaryngoscopy with visualisation of the subglottic area was possible using the above HFJV technique. The findings were of subglottic oedema only and surgery was not needed. The HFJV catheter was removed and after emergence from anaesthesia the infant was found to be able to breathe with minimal stridor and made a full recovery.

Patient 6 was an 8-year-old boy with a history of tracheal stenosis requiring resection and re-anastomosis of the trachea, with periodic dilatations since surgery. Stenosis had resulted from prolonged intubation and tracheostomy after respiratory complications following a splenectomy at 4 years of age. On this occasion he was scheduled for surgery to improve a congenital malformation by construction of a thumb from an index finger. Pre-operatively he had no symptoms or signs of respiratory obstruction. After intravenous induction of anaesthesia it was found that even a 4 mm tracheal tube was too large to pass through the subglottic area. An unwrapped triple lumen catheter was therefore inserted over a guidewire into the trachea and HFJV anaesthesia instituted as described above. Since the laser was not to be employed, 33% oxygen in nitrous oxide could be used. At an early stage in the operation it was noted that the mean airway pressure rose with each jet ventilation until it reached the preset threshold of 0.5 kPa. At this point inhibition of ventilation occurred and allowed the airway pressure to fall. A regular pattern of two jet ventilations followed by a missed ventilation ensued. To improve exhalation of ventilatory gases through the stricture, an 8 French gauge suction catheter was passed alongside the triple lumen catheter and connected to the operating theatre low pressure active scavenging system (Fig. 2). The mean airway pressure stayed at less than 0.5 kPa and HFJV became regular again. The operation lasted more than 3 h and in the recovery and postoperative period the child exhibited no respiratory problems.

Discussion

Over the last 20 years many techniques for general anaesthesia for microlaryngeal laser surgery have been described. The main surgical requirements are a stationary target without obstruction to the surgeons' view or to the path of the laser beam [1]. Any foreign materials in the surgical field must be nonflammable [4] and the environment should not encourage combustion [2].

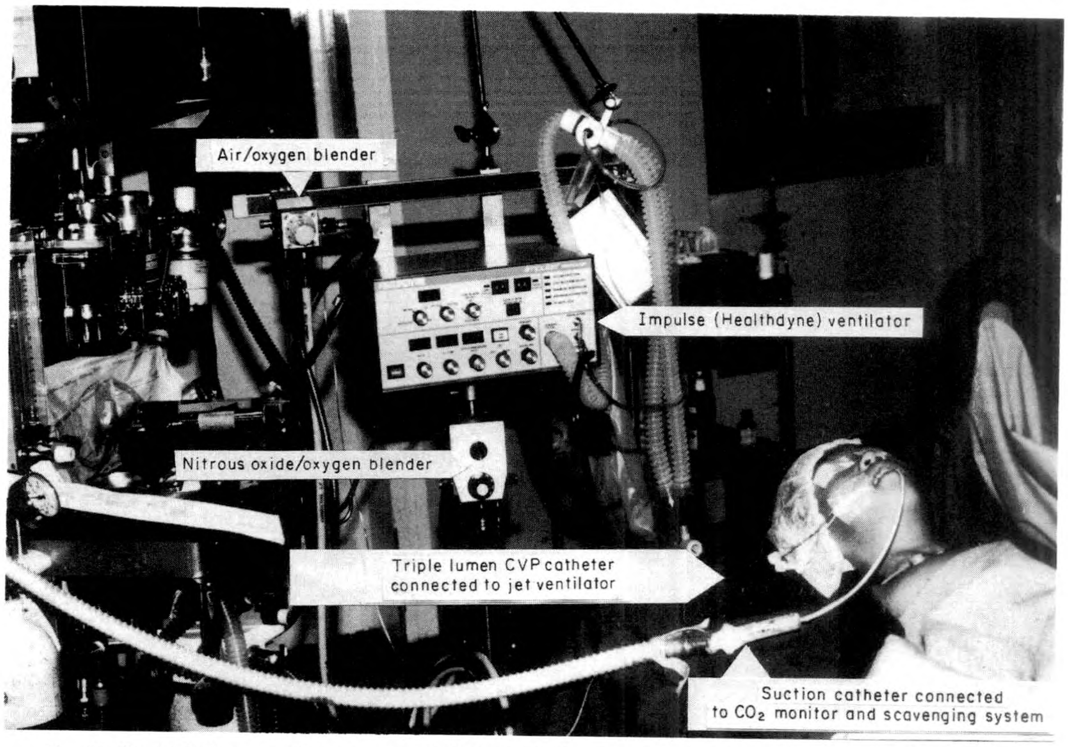
Air/oxygen blender
Impulse (Healthdyne) ventilator
Nitrous oxide/oxygen blender
Triple lumen CVP catheter connected to jet ventilator
Suction catheter connected to CO_2 monitor and scavenging system

Fig. 2. The triple lumen catheter as a conduit for high frequency jet ventilation during anaesthesia (case 6).

Methods of anaesthesia used include intermittent apnoea, spontaneous ventilation using a nasal airway, conventional controlled ventilation using a small nasotracheal tube, jet insufflation via a Sanders apparatus and more recently HFJV. Some authors have combined more than one of these techniques during an operation [5].

Intermittent apnoea allows surgery between periods of ventilation of the lungs by the anaesthetist. Hypoxia and hypercarbia may be a danger, but a clear field for the surgeon can be guaranteed. Frequent interruptions by the anaesthetist will prolong surgery, which may already be lengthy. The airway is not protected from soiling by smoke, surgical debris or blood.

Spontaneous breathing of 3–4% halothane in oxygen, insufflated into the pharynx via a nasal cannula, may be easy in skilled hands [6]. The anaesthetist must be vigilant to ensure patency of the airway and safety of the technique relies heavily on clinical detection of early airway obstruction [7]. The surgical field is clear, but aspiration is a potential problem. This inspired mixture would encourage combustion of materials such as surgical swabs, drapes and tissue fragments [2]. Any hypercarbia would augment the arrhythmogenic potential of high concentrations of halothane. The last two problems could be avoided if total intravenous anaesthesia was used in place of volatile agents.

Conventional controlled ventilation with balanced anaesthesia, using a smaller than usual tracheal tube, has the advantage of familiarity to all anaesthetists and ensures a patent airway. The tube must be made of metal, be metal-coated or be foil-wrapped to prevent combustion [8]. Surgical access to all areas of the glottis and subglottis is difficult, however small the tracheal tube [4] and it may be impossible to use solely this technique in infants who have an already narrowed tracheal inlet [5].

Jet or Venturi ventilation provides air entrainment by an intermittent high pressure oxygen jet from a small gauge needle. With the needle clamped onto the suspension laryngoscope, the view of the glottis is unobstructed. Ventilation may become inadequate if the jet is misaligned and the stomach may be distended, with the risks of regurgitation or vagal stimulation [5]. Barotrauma causing tracheal or bronchial damage may produce pneumomediastinum or pneumothorax [9]. Entrainment of smoke and debris into the tracheobronchial tree may occur and turbulent airflow may produce vocal cord movement [5]. Placement of the Venturi needle deep in the trachea will prevent some of these problems but not that of barotrauma. The inspired gas mixture will have a high oxygen fraction which encourages combustion. The actual concentration depends on the amount of air entrainment, which varies with the depth of insertion of the jet needle into the airway.

HFJV via a small catheter in the trachea provides continuous access to ventilate the patients' lungs undergoing microlaryngeal surgery, whilst allowing good surgical exposure. A low inspired oxygen concentration with absence of nitrous oxide and halothane should decrease the risk of conflagration [2]. The inherent positive end-expiratory pressure produced [10] may help to prevent aspiration into the lungs.

The problem of barotrauma from HFJV exists [3] and has prompted Bourgain and colleagues [11] to develop the GR 300 ventilator that measures the end-expiratory pressure (EEP) and inhibits subsequent breaths if the EEP fails to decrease below a preset, user-selected value. This was the first technique reported for monitoring airway pressure during HFJV which did not require the introduction of a second catheter into the airway.

The technique described in the present paper, using a multilumen catheter with the Impulse 303 ventilator, also overcomes this problem and has additonal advantages. The 16-gauge distal lumen is a suitable diameter for the delivery of HFJV. The middle lumen allows constant monitoring of either peak or mean pressure in the airway. A rise above a preset level can inhibit the Impulse ventilator at any stage during the respiratory cycle. Even with foil wrapping the external diameter is less than 2.5 mm and the flexibility of this cannula allows the surgeon to move it around the glottis and expose all areas for surgery. The catheter tip is soft which may make damage to the trachea less likely than if a rigid metal cannula is used.

The multilumen catheter can be left in place at the end of surgery and ventilation continued until the patient has recovered from neuromuscular blockers and other agents, and is awake and breathing adequately. The potential exists to monitor expired gases continuously provided that the patient is large enough for the proximal lumen to be positioned below the cords.

Movement of the distal end of the flexible catheter might be expected during HFJV. Fortunately, however, the foil wrapping provides a degree of rigidity and in combination with the low driving pressures required for small children this prevents the end of the catheter undergoing a whiplash movement with each pulse.

The cost of the cannula is not, we believe, a significant factor to outweigh the advantages of this technique in the management of a difficult situation. Indeed a custom-made triple lumen catheter in a cheaper material could be manufactured. Relocation of the ports, so that there are three near to the distal end of the catheter, would improve pressure monitoring and provide the facility to sample gases in the airway via the third lumen, even in small infants. Such a catheter with a 4.75 mm diameter has already been made for use in adults and is under evaluation in the authors' department.

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SPECIAL ARTICLE

Clinical measurement and clinical practice

M. K. SYKES

During the last 60 years we have witnessed the transition of anaesthesia from an art to a science. A science may be defined as a body of systematic and formalised knowledge. In anaesthesia we encounter a wide range of scientific disciplines, each of which has a body of knowledge which can be described with a variable degree of precision. However, the one common requirement of all these sciences, whether it be physics or psychology, is that there is a need to measure the input and output functions of the system under study. In the past, such measurements were usually made in a laboratory, since this could be designed to provide the most sympathetic environment for the purpose. But, even in that environment, many measurements proved difficult. The reason was nearly always the same—the problem of the biological interface, where sensor meets tissue and complex reactions occur. It is, therefore, not surprising that many years of development were often required before such measurements could be successfully transferred to the clinical environment.

It is, of course, the development of the microprocessor which has revolutionised the practice of clinical measurement and monitoring over the past two decades. Microprocessors have made a major impact on the processing of data, the control of apparatus function and the display of results in an easily read format. However, the major benefit resulting from their use has been the development of sophisticated artefact rejection algorithms which have dramatically increased the signal-to-noise ratio of many measurement systems. This remarkable advance has not only increased the range of measurements which can be made in the clinical environment, but has also enabled the results to be presented on-line, so that measuring instruments can now be used for the continuous monitoring of the patient's condition.

Many anaesthetists believe that the widespread use of clinical measurement has revolutionised anaesthetic practice and resulted in a reduction in morbidity and mortality. For example, Keenan and Boyan [1] have reported that, in their institution, the incidence of preventable cardiac arrest during anaesthesia in the period 1979–1988 was half that observed during the previous decade, and that this decrease in mortality was due to a decrease in preventable respiratory causes. This change might well be attributed to the increased use of monitoring devices such as end-tidal CO_2 analysers and pulse oximeters during the second decade.

The decrease in mortality has also been accompanied by a reduction in the number of major accidents reported to one of the major medicolegal insurance groups, who were able to reduce their premiums as a result [2]. However, during this period there was a similar reduction in the frequency of claims in a number of other high risk specialties [3]. A number of other factors could well have accounted for the decrease in complications. For example, in 1976 only 52% of anaesthesiology residents in American hospitals were trained in U.S. Medical Schools, whilst in 1988 the figure had risen to over 90% [4]. The staff/patient ratio and average duration of residency training had also increased and it is reasonable to assume that this must have resulted in an improvement in the standard of training.

The Harvard Insurance figures suggest that the decrease in complications coincided with the introduction of the Harvard Standards of Monitoring in 1985 [5], but it must be remembered that the first clause of this document stipulated that the anaesthetist should remain with the patient throughout the anaesthetic, and it is quite possible that this injunction did more to reduce the incidence of complications than the provision of extra monitoring apparatus. Indeed, the real cynics question whether we need any monitoring equipment in the operating theatre at all. They point out that no one has actually proved that any of this expensive equipment produces a higher quality of outcome for the patient, and they suggest that, in many circumstances, its presence may prove counterproductive, in that it may distract the anaesthetist from direct observation of the patient. I think that many of us who have struggled to come to terms with the latest piece of high technology equipment sympathise with this view, for we have all experienced periods when we have become so absorbed in a problem with our equipment that we have not noticed an obvious change in the clinical state of our patient. It thus seems to me that this is an appropriate time to re-examine the question: 'Has clinical measurement really improved clinical practice during this last 60 years?'

In the hope of throwing some light on the problem, I

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propose to examine four of the major problems associated with clinical measurements. These are: (1) the feasibility of the measurement, which largely depends on the biological interface; (2) the accuracy, which is primarily dependent on the design of the measurement system; (3) the interpretation of the measurement, which is dependent on the critical faculties of the observer; (4) the value of the measurement in the care of the patient.

The latter, as we shall see, is a question which has been conveniently overlooked by most clinicians, who, when faced with a difficult clinical problem, naturally find action infinitely more rewarding than contemplation!

Let me first illustrate some of these problems by looking at the value of measurements of central venous pressure, pulmonary artery and wedge pressures, and arterial blood pressure.

Central venous pressure

The Reverend Stephen Hales was the first to measure both central venous pressure and arterial pressure in the horse, dog and fallow doe in the early years of the 18th Century (Fig. 1), and it was he who first pointed out the necessity for referring venous pressure to a clearly defined zero point—in his case the left ventricle [6].

There was little interest in the measurement of venous pressure during the next 150 years but there was then an isolated report from Cohnheim and Lichtheim [7] noting that venous pressure changed with blood volume. Seven years later, Howell and Donaldson [8] showed that venous pressure influenced the work of the heart, whilst the first clinical measurement, using a method similar to that of Hales, was made in 1910 by Moritz and von Tabora [9].

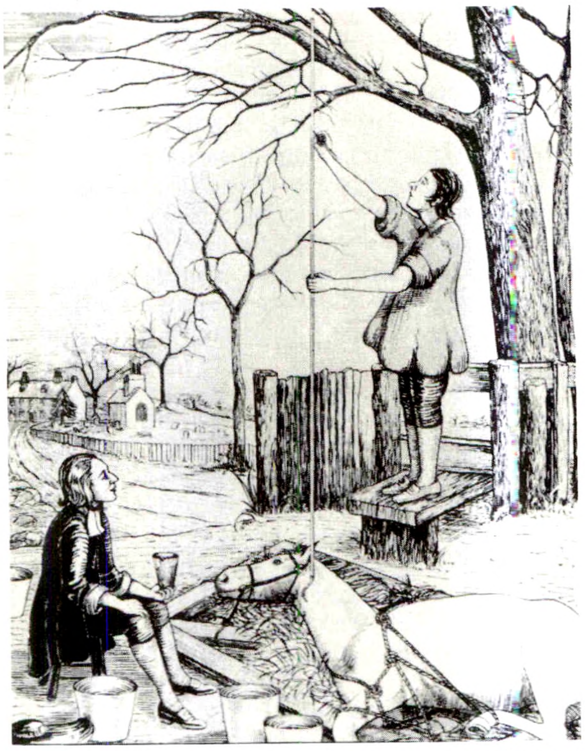

Fig. 1. Artist's impression of Stephen Hales measuring the arterial pressure in a horse. He noted that the blood in the tube rose to a height of 8 feet 3 inches above the left ventricle in one horse, and 9 feet 6 inches in another. Later, he realised that the result might be influenced by the kinetic energy of the blood and used a T-shaped connection between the artery and manometer tube.

By 1915, E.H. Starling was able to summarize his recent work on the role of central venous pressure in the regulation of cardiac output [10]. He said: 'The law of the heart is thus the same as the law of muscular tissue generally, that the energy of contraction, however generated, is a function of the *length* of the muscle fibre.' I stress the word 'length' because we shall later discuss the poor correlation between distending pressure and end-diastolic volume in certain clinical circumstances.

Physiologists continued to be interested in venous pressure and by 1950 Landis and Hortenstine [11] were able to produce a very comprehensive review of the subject, which included a diagram illustrating the many factors influencing venous pressure: the *Vis a tergo* driving blood forward from the capillaries, the lateral pressure created by the balance between blood volume, venous tone and the external pressures, and the opposing *Vis a fronte* generated by the filling pressure of the right ventricle.

By 1955 it had been clearly established that end-diastolic volume was not the only factor affecting cardiac output, but that the latter depended on cardiac contractility as well, and the concept of ventricular function curves had become generally accepted [12]. However, it was the introduction of the heart–lung machine, in the late 1950s and early 1960s, which really brought the importance of venous pressure to the attention of the anaesthetist. Those of us who were involved in anaesthetising patients for open heart surgery gained a great deal of our knowledge from the cardiologists, cardiac surgeons and perfusionists with whom we worked, and it was they who taught us how to manipulate venous pressure to optimise cardiac output in patients with severe heart failure. Later, the anaesthetists who were involved in cardiac anaesthesia became the teachers, and passed on their skills to their colleagues.

As you might anticipate, there are a number of potential sources of error associated with the measurement of venous pressure, and care is required to ensure that the tip of the catheter is in the right place and that a dynamic trace is obtained. There is also a fairly wide range of normal values due to difficulties in establishing the true zero reference point, and to other factors, such as variations in venous tone and posture. However, the major limitation of the measurement is that it only reflects the filling pressure of the right heart, and this may not necessarily reflect the filling pressure of the left ventricle.

Despite these disadvantages, one can obtain very valuable information about the state of the circulation if one observes the response to a small brisk transfusion (Fig. 2). A transfusion of about 200 ml of fluid given over a 2 min period results in practically no change in central venous pressure in a hypovolaemic patient. In the patient with a normal heart and blood volume the pressure increases by 1–2 cmH_2O during the transfusion but then rapidly returns to pre-existing levels, whilst in the patient who is overloaded or in cardiac failure there is a much greater increase in pressure, which tends to be sustained.

I think most anaesthetists would now agree that there are four main indications for the measurement of central venous pressure, and that, within these constraints, the measurement provides clinically useful information with a minimal degree of risk. The four indications are: (1) to help

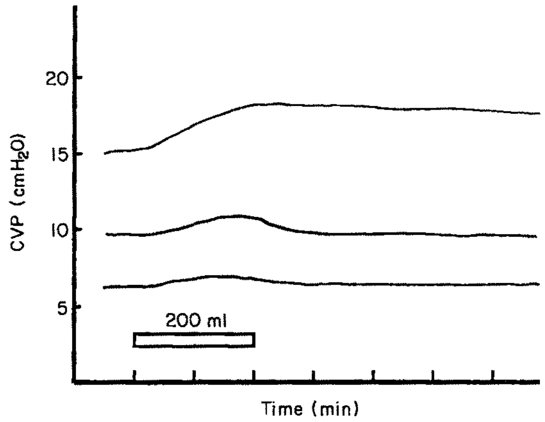

Fig. 2. Effect of transfusion on central venous pressure. In the hypovolaemic patient the initial pressure is low and transfusion produces little effect. In the normovolaemic patient the venous pressure is higher, increases during the transfusion, but returns to the pre-existing value when the transfusion is stopped. When the patient is overloaded or in right heart failure the initial pressure is high, increases rapidly during transfusion and remains high when transfusion is stopped.

diagnose the cause of a sudden, unexplained hypotension; (2) to monitor transfusion in acute, massive blood loss; (3) to monitor transfusion in anaemic patients; (4) to monitor right heart filling pressure in patients with acute heart disease.

Pulmonary artery and wedge pressure

What, then, of measurements designed to provide information about the filling pressure on the left side of the heart?

The history of the pulmonary artery flotation catheter goes back to Lategola and Rahn, who described the use of a balloon catheter in animals in 1953 [13]. Dotter and Straube [14] then reported the use of a soft plastic catheter for radiological purposes, and in 1964, Bradley, at St Thomas's Hospital, described how very fine nylon catheters could be floated into the pulmonary artery in humans [15]. However, those of us who tried to emulate him found that the success rate was not very high, and it took over a minute to obtain a 1 ml blood sample through the 0.5 mm bore of the catheter. Furthermore, it was necessary to use a very high quality transducer to obtain a satisfactory frequency response. The introduction of the Swan–Ganz catheter in 1970 [16] therefore represented a very significant advance, not only because of the relative ease with which the catheter could be passed, but also because of the amazing quality of the catheter and balloon, so different from the crude inflatable cuffs on tracheal tubes to which we had become accustomed.

The pulmonary artery catheter can provide a measurement of pulmonary artery pressure or can be wedged in one of the medium sized branches of the artery to provide an estimate of left atrial pressure.

Obviously, the pulmonary artery pressure is affected by the resistance of the pulmonary vascular bed. However, if we have a good dynamic trace we can use the pulmonary artery end-diastolic pressure as an index of left-sided filling pressure, since flow at end-diastole should be zero, and there should transiently be a static column of blood connecting the pulmonary artery to the left side of the heart. This is a useful way of estimating left atrial pressure if one cannot wedge the balloon, and it also has the advantage that the measurement can be made continuously without running the risk of infarcting the lung. However, the validity of the measurement depends on the assumption that there is no flow through the lung at end-diastole. This is usually true if the lung is normal and the heart rate less than about 100 beat.min^{-1} but may not be so if pulmonary vascular resistance is increased from any cause, or if there is a tachycardia.

The use of the wedged catheter overcomes these problems by ensuring that there is no flow in the pulmonary vascular bed distal to the balloon. Providing the criteria for correct wedging are complied with, pulmonary wedge pressure should then equal left atrial pressure. Unfortunately, this assumption may not be valid. One source of error is that the hydraulic bridge between the pulmonary artery and left atrium may be interrupted by compression of the pulmonary capillaries. To avoid this it is necessary to ensure that the tip of the catheter is placed in West's zone 3 of the lung, so that the continuity of the fluid column is maintained, even when a positive end-expiratory pressure is applied to the airway. But whilst inflation of the balloon may secure a stationary column of blood in a segment of the lung, there is still flow through the pulmonary veins, left atrium and mitral valve, and any obstruction to this flow will result in a gradient of pressure between the tip of the catheter and the ventricle, so that wedge pressure may overestimate left ventricular filling pressure. This error may be seen in patients with a left atrial myxoma, mitral stenosis or an artificial mitral valve. Pulmonary wedge pressure may also be greater than ventricular filling pressure in patients who have large 'v' waves due to mitral regurgitation, or in patients with a decreased left atrial compliance or a large left-to-right shunt. Conversely, left ventricular end-diastolic pressure may exceed left atrial pressure when aortic regurgitant flow causes premature closure of the mitral valve. We thus face the problem that there are many potential sources of error in measurements made through a pulmonary artery catheter and that these can make the interpretation very difficult at the time when we most need the measurement.

In addition to all these difficulties we have to consider a problem of even more fundamental importance, for when we are considering the factors governing ventricular ejection we need to know left ventricular volume rather than filling pressure, since this is the true determinant of stroke volume. We now know that in patients with ischaemic heart disease, or in the period immediately after open heart surgery, ventricular compliance is often decreased so that pulmonary wedge pressure becomes a poor predictor of left ventricular end-diastolic volume. Thus, an increased wedge pressure may indicate that a normal left ventricle has been overfilled (Fig. 3(a)), but it may also result from a decrease in left ventricular compliance (b) or from a reduction in left atrial compliance due to an increase in the pressure surrounding the atrium (c).

It is apparent that the difficulties of passing the catheter in some patients, and the large number of potential sources of error, greatly reduce the value of the method. For example, in one recent study in two Intensive Care Units an error of more than 4 mmHg in wedge pressure measurement was encountered in 14% of the observations [17]. But, we also have to consider the high incidence of complications associated with the use of Swan–Ganz catheters.

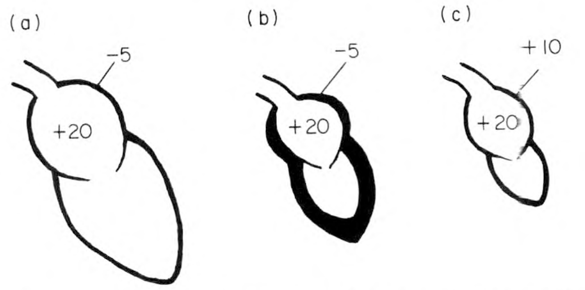

Fig. 3. Three possible interpretations of a high pulmonary wedge pressure (20 mmHg): (a) distension of a normally compliant heart; (b) normal or diminished preload with a noncompliant ventricle; (c) high juxtacardiac pressure with normal or decreased end-diastolic volume (preload).

These include: perforation of major vessels, damage to heart valves, knotting, bursting of the balloon, arrhythmias, infection, thrombosis, embolism and infarction of the lung—a fairly formidable list. These are not infrequent. For example, Boyd *et at.* [18] found that there were complications in 24% of 528 insertions in 500 patients, and that 4.4% of the complications were life-threatening. Again, Rowley *et al.* [19] studied 142 consecutive autopsies, in 55% of which a pulmonary artery catheter had been inserted. They reported that there were right-sided endocardial lesions in 53% of patients who had received a catheter, and that 7% of these had proven infective endocarditis.

E.D. Robin has repeatedly warned of the dangers of pulmonary artery catheters [20], and in 1988 [21] he commented freely on an extensive correspondence which followed the publication of an article by Gore *et al.* [22] in a previous issue of the journal. This was a retrospective study of a large number of patients who had had an acute myocardial infarction in 1975, 1978, 1981 and 1984. The authors found that the in-hospital fatality rates in patients with congestive heart failure or severe hypotension were significantly higher in those patients who were managed with a catheter than in those managed without. They also found that patients with catheters had a longer hospital stay than those who had not received a catheter, although the 5-year survival rate was the same in both groups. Although the authors stated that examination of the case notes failed to reveal any significant difference in the initial clinical status of those receiving catheters and those without, it is difficult to refute the suggestion that the increased mortality in the catheter group was due to the fact that they were more seriously ill than the patients who did not receive a catheter. It is obvious that this question can only be answered by a properly controlled, randomised trial. So far, only two groups have, to my knowledge, taken up the challenge, and they, unfortunately, have a sorry tale to tell.

In the first trial, Tuman *et al.* [23] attempted to determine whether a pulmonary artery catheter affected outcome in 1094 consecutive patients undergoing open-heart surgery. The anaesthesia was provided by a group of nine anaesthetists, some of whom regularly inserted pulmonary artery catheters, and some of whom did not. They thus allowed the anaesthestist's choice to provide the randomisation. Obviously, this strategem is not acceptable, even when accompanied by a highly sophisticated statistical analysis, but it is of interest that the authors failed to find any significant difference in mortality between those who received catheters and those who did not. The second trial [24] failed to generate enough participants because of the preconceived notions of the doctors taking part! We are thus left with a situation where we have a measurement modality which is potentially of immense value, but with no concrete evidence that it has any effect on morbidity or mortality.

Arterial pressure

Let me now turn to arterial pressure. Surely, we have here a measurement which is easy to make, has acceptable accuracy and which had been shown to be crucial to outcome?

As you can see from this picture of Joseph Clover anaesthetising a patient in the sitting position (Fig. 4), blood pressure measurement came rather late to our clinical scene! It was, indeed, a surgeon, Harvey Cushing, who first suggested that blood pressure should be measured during anaesthesia. Cushing had been deeply upset by the death of a patient during an anaesthetic which he had been asked to administer whilst he was still a medical student, and when he entered surgical practice he instituted the recording of temperature, pulse and respiration rate, on what later became known as 'ether charts'. Several years later, he spent some time studying in Italy and learnt of Riva-Rocci's method of measuring systolic pressure by the use of an inflatable cuff. When he returned to Boston he started to use this technique in surgical patients and published the first paper on its use in 1902 [25]. By 1903 he had succeeded in interesting the other surgeons at the

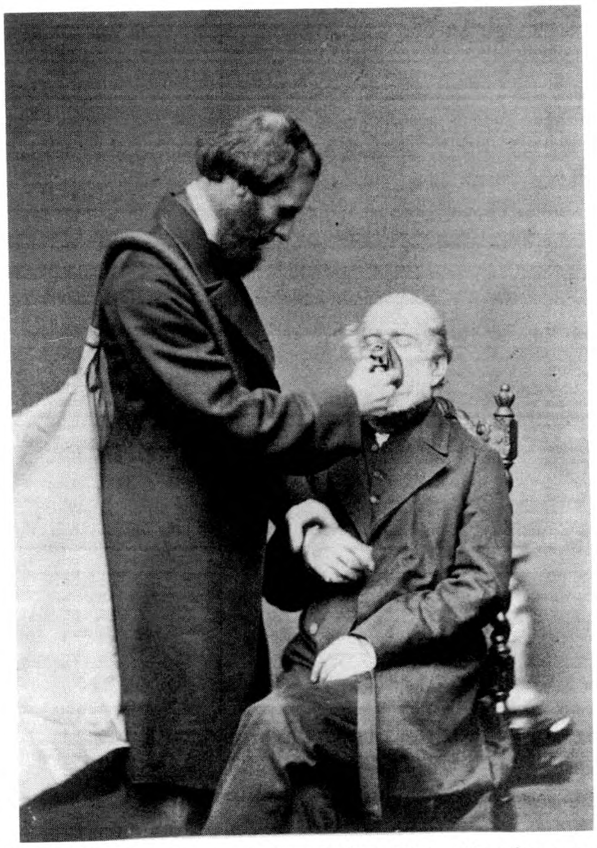

Fig. 4. Joseph Clover demonstrating how chloroform was administered with his apparatus. Note the finger on the pulse and the rigid, upright stance of the patient! (From an original photograph donated to the Nuffield Department of Anaesthetics, Oxford, by his daughter, Miss Mary Clover).

Massachusetts General Hospital (MGH) in blood pressure measurement and they instituted a trial within the hospital. However, the method did not catch on at the MGH and in March 1904 the committee concluded: 'The adoption of blood pressure observations in surgical patients does not at present appear to be necessary as a routine measure.' Although Cushing continued to use blood pressure measurement in his own practice, and its use spread slowly to other hospitals, Cushing himself seemed to take rather a cynical view of the value of the measurement in retirement! In April 1930 [26] he wrote to a colleague: . . . 'but I am not so sure that the general use of a blood pressure apparatus in clinical work has done more than harm. Just as Floyer's pulse watch led to two previously unknown diseases, tachycardia and bradycardia, so the sphygmomanometer has led to the uncovering of the diseases . . . of hypertension and hypotension, which have greatly added to the number of neurasthenics in the world.'

Nowadays, no patient is allowed to be anaesthetised without some form of blood pressure measurement. However, we must never forget that accuracy is difficult to achieve. Even with modern instruments we may encounter errors as high as 20 mmHg in diastolic pressure when we rely on noninvasive measurements, and although the technique of direct measurement has improved immeasurably over the last 20 years, it is disturbing to see how few clinicians use the simple square wave test to check the frequency response and damping of the catheter–transducer systems they use, even though an underdamped system may well lead to a 20% over-estimation of the systolic pressure. I think all anaesthetists should be constantly reminded of Ty Smith's aphorism that, just as a tube in the trachea does not guarantee a patent airway, so a catheter in an artery does not guarantee an accurate blood pressure reading.

But let us suppose that we have an accurate measurement. What is its value? I think most of us are now convinced that extremes of blood pressure may be harmful to the patient, although the limits considered safe vary greatly between individual anaesthetists. Obviously, there are many aspects of the patient's condition which will influence the anaesthetist's response to a given change in blood pressure, but the complexity of the variables present in any individual patient makes this a very difficult field to study objectively.

Of more concern is the value of blood pressure measurement when it is within the normal range. We all know that the body has homeostatic mechanisms which maintain arterial pressure close to normal in the presence of a 10–15% blood or plasma loss. We also know that there is a major leak of protein-rich fluid into the gut in patients having major bowel surgery, and yet it is not uncommon for anaesthetists to fail to give a colloid transfusion to such patients when there has been no overt blood loss, just because the arterial pressure is normal. They are then surprised how rapidly the arterial pressure falls when blood loss does occur.

I remember making a similar mistake in the early days of open-heart surgery when we were attempting the first operations for total repair of the Tetralogy of Fallot. The patient was an 8-year-old girl. After the operation she was restless, cyanosed and vasoconstricted, but had a systolic arterial pressure of 90 mmHg. This was considered fairly satisfactory for someone who had undergone open-heart surgery at that time, but we were concerned that her conscious level was deteriorating. This was long before the days of Swanz–Ganz catheters, but I was able to get a blood sample from the superior vena caval line which showed a saturation of 72%. We did not then recognise the syndrome of intense peripheral constriction with almost complete redistribution of all the blood flow to the vital organs and we had no measurements of cardiac output. However, we had recently started to measure oxygen consumption, and I am sure that, if we had done so in this patient, we would have found it greatly reduced, and would have realised what was happening to the circulation. Whether we could have prevented this patient's demise by vasodilatation and augmentation of blood volume is open to question, but the point is that we were making the few measurements which were available to us, but were not thinking carefully enough about the interpretation of the results. Unfortunately, this is a problem which is still with us today. Time and again one sees an anaesthetist assuming that the patient's condition is satisfactory because the arterial pressure is normal when a casual glance at the veins on the back of the hand, or even a look into the wound, would tell them that significant blood loss had occurred, and that arterial pressure was only being maintained by compensatory venoconstriction.

This failure to question the significance of the measurement is not limited to measurements of pressure but applies to the majority of the measurements which we make today. Let us look at one of the most popular measurements, that of end-tidal $P\text{CO}_2$ (Fig. 5). This, as we know, tells us about the balance between CO_2 production and alveolar ventilation. However, alveolar ventilation depends not only on total ventilation and the various components of dead space, but also on the CO_2 content of the gas supplied to the lungs by the breathing system. On the other side of the equation, we have not only the various factors affecting CO_2 production, but also those affecting its transport from the tissues to the lungs. We are thus dealing with a highly complicated system in which multiple factors may influence end-tidal CO_2, and some inspired guesswork is sometimes required to identify the cause of a change in the reading. The system is made even more complicated by the fact that the arterial CO_2, which is what we are really interested in, bears a very variable relationship to end-tidal CO_2 during anaesthesia. In the patient who has lost blood we may thus have a decreased CO_2 production, decreased CO_2 transport to the lungs and an increase in alveolar dead space, each of which will contribute to a decrease in end-tidal CO_2. But even if we measure arterial CO_2, we can still make mistakes. I well remember one very diligent registrar who measured the blood gases on a patient who had undergone open-heart surgery earlier in the day and found that the $P\text{CO}_2$ was about 8 kPa. With the great theoretical knowledge resulting from a recent successful confrontation with the examiners, he interpreted this as ventilatory failure and put the patient on a ventilator. What he had forgotten, of course, was that the increased CO_2 was a compensatory respiratory acidosis for a nonrespiratory alkalosis resulting from the metabolism of the citrate in the large quantities of blood that had been administered during the day.

We have similar problems with pulse oximetry. Most anaesthetists are well aware that there are many sources of inaccuracy in the measurement. There are also a number of occasions when the signal is inadequate and the machine

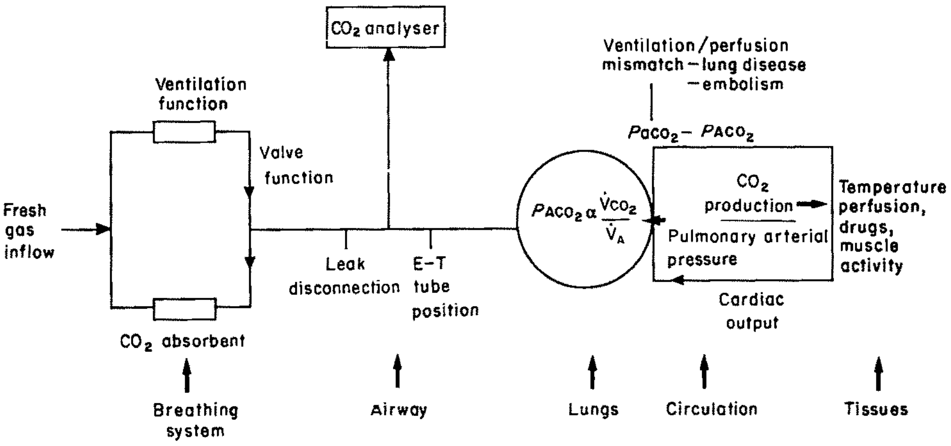

Fig. 5. Factors affecting the end-tidal $P\text{CO}_2$ ($P\text{ACO}_2$) and the arterial to end-tidal $P\text{CO}_2$ difference ($P\text{aCO}_2$–$P\text{ACO}_2$) during anaesthesia. Although $P\text{ACO}_2$ depends primarily on the relationship between CO_2 production ($\dot{V}\text{CO}_2$) and alveolar ventilation ($\dot{V}_A$), it is also influenced by cardiac output, ventilation–perfusion mismatch in the lungs and the CO_2 content of the ventilating gas mixture.

fails to make a reading at all. In one recent study [27] the overall failure rate throughout the hospital was over 1%. However, even if we succeed in making an accurate measurement we still have to interpret the results.

Figure 6 summarises the most common causes of arterial hypoxaemia—a reduction in inspired oxygen concentration, hypoventilation, and an increase in venous admixture or intrapulmonary shunt. However, it should be noted that the decrease in saturation resulting from a given shunt depends on the saturation of the blood passing through the shunt, and this, in turn, depends on tissue oxygen consumption and cardiac output.

We now know that within a few minutes of induction of anaesthesia with either spontaneous or controlled ventilation, areas of compression collapse appear in the dependent zones of the lungs in 95% of patients [28], and that these result in an increase in intrapulmonary shunt to values of 10–20%. During abdominal surgery the magnitude of this shunt may be increased by further collapse, particularly if the patient is obese or the surgeon is exploring around the liver. In both circumstances the increase in dependent zone collapse not infrequently results in arterial desaturation, even if the patient is being ventilated with 30% oxygen. However, the desaturation can be reversed, at least partially, by hyperinflating the lungs.

But sometimes we see a slowly progressive arterial desaturation which has no apparent cause, and which does not respond to hyperinflation, but does respond to the infusion of fluid. The cause of the desaturation in this case is quite different. Usually, there has been a progressive fluid loss which results in a decrease in cardiac output, although arterial pressure may be maintained by vasoconstriction. The decrease in cardiac output leads to a decrease in pulmonary artery pressure and this, in turn, results in decreased perfusion of the well-ventilated upper parts of the lung. Although the actual flow through the shunt in the dependent area of lung may be unchanged, it now constitutes a greater *proportion* of the reduced total flow and so effectively increases the *percentage* of shunt, with a consequent decrease in arterial saturation (Fig. 7). The decreased blood volume and cardiac output also decrease mixed venous oxygen saturation and this accentuates the arterial desaturation. The key to elucidating the true cause of the

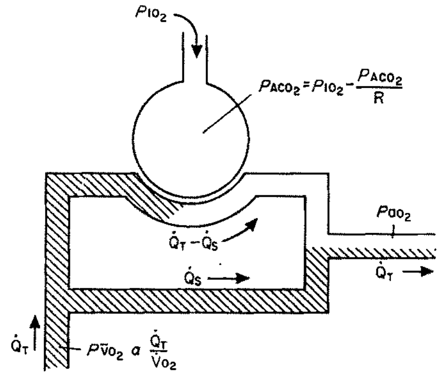

Fig. 6. Arterial oxygen saturation depends on arterial $P\text{c}_2$ ($P\text{aO}_2$), which, in turn, depends on the inspired $P\text{O}_2$ ($P\text{IO}_2$), alveolar ventilation and the percentage shunt ($\dot{Q}_s/\dot{Q}_T$). However, the effect of the shunt will also depend on mixed venous $P\text{O}_2$ ($P\bar{v}\text{O}_2$) and saturation, which in turn depends on cardiac output ($\dot{Q}_T$) and oxygen consumption ($\dot{V}\text{O}_2$)).

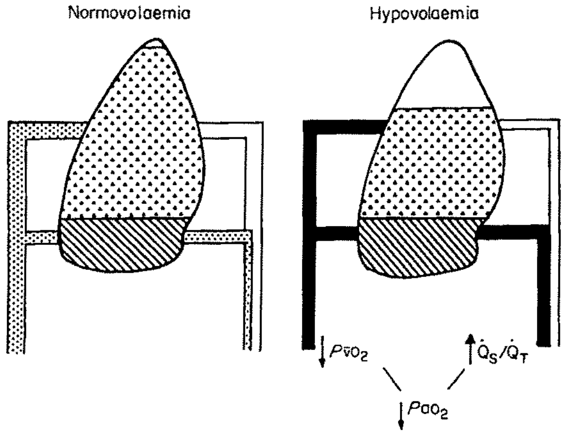

Fig. 7. Hypovolaemia may cause arterial desaturation in a patient with dependent zone collapse by decreasing the pulmonary artery pressure and the perfusion of ventilated upper zones. Although flow through the collapsed area may be unchanged, it now represents a higher proportion of the total flow so that the percentage shunt is increased. The resultant decrease in arterial saturation is accentuated by a reduction in mixed venous $P\text{O}_2$ and saturation resulting from the decrease in cardiac output.

hypoxaemia in this type of situation is the response to two or three hyperinflations of the lungs. If the cause is progressive collapse, the hyperinflations will produce a transient decrease in arterial saturation of 2–3%, followed by an increase to the levels which existed before the collapse occurred. The transient decrease in saturation in response to the hyperinflations is due to the increase in the nonperfused area of lung and to the decrease in mixed venous saturation resulting from the transient fall in cardiac output produced by the hyperinflations. When the normal intrathoracic pressure is restored the cardiac output returns to normal and the full benefit of the re-expansion procedure becomes apparent. If there is no response to hyperinflations it is worth giving a transfusion, even if there are no overt signs of blood loss. It is surprising how often this restores the arterial saturation to its previous level.

Now, I have been very critical of some of the clinical measurements which all of us have relied on, and I would not like you to go away thinking that I believed that they were of no use in anaesthesia or intensive care! Obviously, an abnormal measurement must alert us to some possible disturbance of function in the patient and therefore must improve clinical care. Many years ago, Comroe and Botelho [29] showed that, even under ideal conditions in the laboratory, the majority of physicians failed to recognise arterial desaturation in volunteers breathing hypoxic gas mixtures until the saturation had decreased to 80%, whilst a quarter of the observers could not recognise cyanosis until the saturation had decreased to 70–75%. There have now been several studies showing that unrecognised arterial hypoxaemia is common in anaesthetised patients. For example, in one Danish study [30] 20% of the patients studied had an arterial saturation of less than 81%, and 70% of these episodes were not detected by the anaesthetist.

But, even better, I can actually quote a randomised, controlled trial which demonstrates that pulse oximetry can improve clinical practice! In this study [31] patients undergoing routine paediatric surgery were divided into two groups, each of 76 patients. Pulse oximetry measurements were made on all the children by an independent observer, but in one group the anaesthetist was allowed to see the display whilst in the other group only the observer could see what was happening. It was found that the incidence of major events (a saturation of less than 85% for more than 30 s) was significantly higher in the patients who were anaesthetised without the knowledge of the arterial saturation. This is one of the very few studies which actually demonstrates that a clinical measurement can influence standards of care, and is a model of the kind of study which ought to be performed whenever some new modality is introduced into clinical practice.

One other development from the application of new methods of measurement is an extension of our knowledge about a particular problem. An example is the use of pulse oximetry to study nocturnal hypoxaemia after operation. We have known for many years that there is a high incidence of pulmonary complications after major abdominal surgery, and that arterial hypoxaemia may persist for several days after surgery [32]. However, measurements were usually made during the day when patients were awake. The advent of the pulse oximeter has now enabled us to study the patient over more prolonged periods of time, and, in particular, to find out what happens to the patient throughout the night. The results are dramatic. For example, Catley *et al.* [33] studied patients during the first 16 h after hip surgery or cholecystectomy. They found that patients given regional analgesia for pain relief had significantly less hypoxaemia than those given an intravenous infusion of morphine. They also demonstrated that the patients given morphine had frequent episodes of central and obstructive apnoea with smaller tidal volumes and a slower respiratory rate than those given regional analgesia. Recently, Reeder has published observations on nocturnal oxygen saturation levels in a group of patients undergoing major arterial surgery in Oxford [34]. These patients were studied whilst breathing air on the pre-operative night and for 5 nights after operation. The pulse oximeter signals were recorded every second throughout the night and average values calculated by a specialised computer programme. He found that over 50% of the patients spent prolonged periods with a pulse oximeter reading of less than 85% saturation on at least one of the postoperative nights, and that nocturnal desaturation persisted for at least 5 nights after operation. The recordings showed that episodes of severe desaturation were superimposed on stable periods of hypoxaemia and that these dips in saturation were often associated with marked tachycardia and hypertension. The value of this type of study is that it reveals the great variability of saturation levels throughout the night, and also demonstrates that oxygen therapy may need to be continued for at least 3 nights after operation in this type of case. Reeder was also able to demonstrate that those patients who had an average saturation of less than 94% throughout the preoperative night were very likely to develop severe postoperative nocturnal desaturation, whilst awake measurements had no predictive value. In this study the pulse oximeter produced data which had been unobtainable before, and it has caused us to rethink our methods of caring for such patients.

It is obvious from all these examples that many of the measurements currently available to us only provide information about one aspect of a physiological system, and often that measurement is but distantly related to the centre of our interest. For example, we can now measure arterial oxygen content and cardiac output and so determine total oxygen transport to the tissues. However, we have no easy means of determining the distribution of blood flow, nor of monitoring the utilisation of oxygen by the cell, although this is the centre of our interest. Attempts are still being made to use infrared spectroscopy to measure redox potential in the brain, but so far without much success. Other new technologies are becoming available. For example, there is at the moment, a great interest in intragastric pH measurement as an index of splanchnic blood flow. Problems with gut function are one of the major causes of postoperative morbidity after abdominal surgery and it is surprising that so little attention has been paid to this aspect of physiology in the past. But, once again, we are looking at a measurement which is not only based on a possibly invalid assumption (that the bicarbonate concentration in the mucosa of the stomach is the same as that in arterial blood), but one which is also the end result of many different physiological processes [35].

Despite all my strictures I think we have to accept that the explosion in the use of clinical measurements which has occurred in the last 40 years has significantly altered our clinical practice, and I for one would not like to go back to the days when we talked of status lymphaticus as a cause of death, or of neostigmine-resistant curarisation as a cause of failure to breathe at the end of an operation. However, I believe that the major contribution which clinical measurement has made to anaesthesia is that it has brought physiology, pharmacology, physics and biochemistry into the operating theatre and intensive care unit. By so doing it has enormously enriched our lives and given us a much higher status in the eyes of our surgical and medical colleagues. To safeguard this heritage we must not only seek out new ways to measure the vital functions which are of most importance to the anaesthetised patient, but we must also ensure that these are properly evaluated by rigidly controlled trials before they are accepted into clinical practice. Above all, we must seek to encourage a healthy scepticism in our trainees. This can only come from a study of science, which, if properly pursued, will ensure that those measurements which are currently available are used appropriately, whilst those which are under development receive the careful consideration and evaluation they deserve. When this has been achieved clinical measurement will have come of age.

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Anaesthesia, 1992, Volume 47, pages 433–434

Forum

The human wedge

A manoeuvre to relieve aortocaval compression during resuscitation in late pregnancy

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Summary

The important part of resuscitation in late pregnancy is the relief of aortocaval compression. A manoeuvre to relieve aortocaval compression (the human wedge) is described and evaluated. Eighteen qualified midwives performed basic life support in the supine and wedged position employing the human wedge. Performance was assessed using the Laerdal Resusci Anne Skillmeter. There was no difference (p = 0.4761) in performance of mouth-to-mouth expired air ventilation between the two positions. External cardiac compressions were performed significantly better (p = 0.0005) in the wedged position than in the supine position. The human wedge may provide an alternative to other methods of relieving aortocaval compression.

Key words

Heart; cardiac massage.
Pregnancy.

Cardiac arrest occurs once in every 30 000 deliveries [1] and survival is rare unless the arrest occurs during general anaesthesia [2]. Aortocaval occlusion may play a significant role in the outcome following cardiac arrest in the pregnant woman and it should be relieved during cardiopulmonary resuscitation (CPR); this is supported by veterinary work [3]. Marx [4] and Lindsay and Hanson [5] have reported the success of early Caesarean section in patients suffering cardiac arrest near term. The early removal of aortocaval compression by operative delivery may be a factor determining successful outcome. Conventional CPR in the supine position is unlikely to be successful in late pregnancy due to the effect of aortocaval compression on venous return.

Aortocaval compression may be relieved by either manual displacement of the gravid uterus or placing the patient in an inclined lateral position. The Cardiff wedge described by Rees and Willis [6] is an example of the latter method. The wedge is made of laminated wood on castors which allow easy transportation and there is a fixed side piece to maintain the patient in a wedged position. Rees and Willis reported that CPR could be performed just as well using the Cardiff wedge as in the supine position.

Unfortunately Cardiff wedges are rare in many British maternity units and the need for prompt relief of aortocaval compression has stimulated the development of a new technique. The human wedge may be used to relieve aortocaval compression by providing a position that is stable and firm enough to perform adequate basic life support.

The human wedge

The person employed as the human wedge need not be medically trained. They kneel on the floor, sitting on their heels. The patient to be resuscitated is positioned so that their back is on the thighs of the human wedge. The human wedge then uses one arm to stabilise the patient's shoulders and the other arm to stabilise the pelvis as seen in Figure 1. The head may be stabilised with a pillow or rolled up item of clothing.

It was decided to evaluate the adequacy of external cardiac massage and mouth-to-mouth expired air ventilation employing the human wedge manoeuvre, using the Laerdal Resusci Anne Skillmeter.

Method

Qualified midwives at the Rosie Maternity Hospital, Cambridge, who attended a resuscitation update, agreed to assist with the study. The midwives were given a basic life support update and then, having practised, were asked to perform basic life support on a Laerdal Resusci Anne Skillmeter in the supine and wedged position employing the human wedge manoeuvre. The percentage of correct chest

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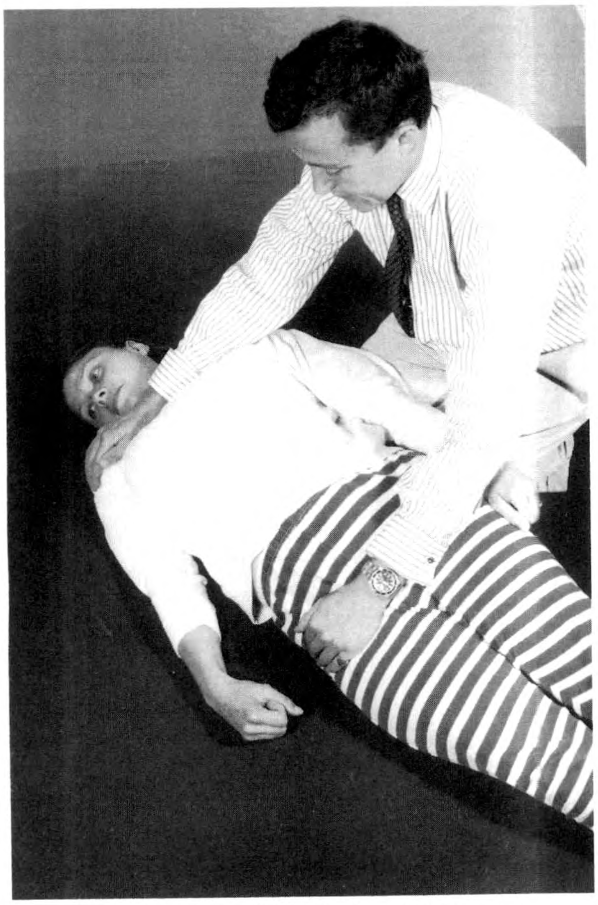

Fig. 1. The human wedge position.

Table 1. Mean (SD) percentage correct external cardiac compressions and expired air ventilations in the supine and wedged position using the Human Wedge manoeuvre performed by 18 midwives.

	Supine	Wedged position
External cardiac compressions	32.5% (24.9)	66.6% (21)*
Expired air ventilation	62.2% (21.4)	56.7% (27.7)

$p = 0.0005$.

compressions and ventilations were recorded in both positions. Data were analysed using paired *t*-tests. Statistical significance has taken as $p < 0.05$.

Results

Eighteen midwives completed the assessment. The results are shown in Table 1. External cardiac compression was performed significantly better in the wedged than in the supine position ($p = 0.0005$). There was no difference in the performance of mouth-to-mouth resuscitation ($p = 0.4761$). The commonest cause for inaccurate external compression was compression of too great a force. The commonest cause for inaccurate ventilation was ventilations of small volume. The midwives found the human wedge manoeuvre easy to perform although some complained of painful knees.

Discussion

The value of early resuscitation initiated by a bystander is recognised [7]. Whilst it may take time to collect a Cardiff wedge, should the hospital be lucky enough to have one, during labour the attendant midwife is instantly available. Pillows and other foam rubber wedges tend to slip during resuscitation or the patient may even fall into the prone position. The human wedge manoeuvre prevents both slipping and rolling and has the added advantage that it may be used in the street by any person initiating basic life support in the pregnant women.

The Cardiff resuscitation wedge has been shown to be adequate for basic life support in the pregnant patient [6]. However, it is not available in all hospitals or, for that matter, in all areas where a cardiac arrest might occur. Manual displacement of the uterus may be satisfactory in relieving aortocaval compression but requires some knowledge to perform well. The human wedge manoeuvre may be employed anywhere by anybody and it has been shown in this study that external cardiac compressions and ventilations are clinically adequate in this position. Perhaps this manoeuvre should be widely adopted.

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We thank the midwives at The Rosie Maternity Hospital for participating in the study.

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Epidural pethidine and bupivacaine in labour

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Summary

A double-blind randomised study was performed to assess the value of the addition of pethidine 50 mg to the initial dose of bupivacaine given for epidural analgesia in labour. Forty-nine patients received either 1 ml of saline ($n = 24$), or 50 mg of pethidine ($n = 25$), added to 9 ml of 0.25% bupivacaine as an initial injection for intrapartum epidural analgesia. There was a significant increase in the mean duration of analgesia in the pethidine group. However, pethidine did not increase the speed of onset of analgesia, or improve the quality of analgesia.

Key words

Analgesics; pethidine.
Anaesthesia, obstetric; epidural.
Anaesthetic agents, local; bupivacaine.

Epidural analgesia with local anaesthetics is an effective, reliable method of pain relief in labour. However, it is also associated with potentially troublesome side effects including hypotension, motor block, shivering and the possibility of systemic toxicity. In an attempt to reduce the overall dose of local anaesthetic required, and hence the incidence of side effects, opioids have been combined with the local anaesthetic. Combinations of bupivacaine with fentanyl, butorphanol, sufentanil or diamorphine have been shown to give a more rapid onset of action, increase the duration of effect, and lower the total dose of bupivacaine used when compared to bupivacaine alone [1–5]. The combination of morphine with bupivacaine is less effective [6]. We have investigated the effect of adding 50 mg of pethidine to the initial dose of epidural bupivacaine used for analgesia in labour.

Method

All patients requesting epidural analgesia during labour were considered as to their eligibility for inclusion in the study, which was approved by the local hospital ethics committee. Written informed consent was obtained from all participants. Patients with multiple pregnancy, weight greater than 100 kg at the initial antenatal visit, cervical dilatation greater than 6 cm, or who had received opioid analgesia within 2 h of epidural insertion, were not studied.

Following establishment of intravenous access, all patients were given 500 ml of compound sodium lactate solution. The epidural space was located between the second and third, or the third and fourth lumbar vertebrae, using the loss-of-resistance-to-air technique and an epidural catheter inserted. The patients were randomly allocated to receive one of two solutions. The solutions were prepared by the staff in the delivery suite and consisted of either 1 ml (50 mg) of pethidine, or 1 ml of saline added to 9 ml of 0.25% bupivacaine. The anaesthetist was unaware of the identity of the solution. Initially 4 ml of this solution was given as a test dose to check for correct placement of the catheter. This was followed 5 min later by the remaining 6 ml. The patient's blood pressure was measured every 5 min for 20 min following the epidural injection. The height and distribution of sensory block was assessed using ethyl chloride spray, at 10, 20 and 30 min following the main injection. The pain of uterine contractions was assessed by the patient using a 100 mm visual analogue scale (VAS), where 0 = no pain, and 100 = the worst pain imaginable. Assessments were made immediately before the epidural was inserted, and at 10, 20 and 30 min following completion of the injection. The time taken from epidural completion to the first painless contraction was also noted. After 30 min, the adequacy of the pain relief was assessed, and the presence of perineal pain or incomplete analgesia was noted. If pain relief was inadequate, further bolus doses of 5 ml of 0.5% bupivacaine were given, and the patient took no further part in the study. The degree of motor block was assessed using a modified Bromage scale (4 = no weakness, 3 = impaired movement at the hip joint, 2 = impaired movement at the knee, 1 = impaired movement at the ankle). Patients were also asked about the presence of itching, nausea, drowsiness or shivering. When the patient requested a 'top-up', the height of the sensory block was ascertained, and the level of pain assessed with a VAS. Ten ml of 0.25% bupivacaine was given as a 'top-up' dose, and an epidural infusion of bupivacaine 0.125% started at $7\ \text{ml.h}^{-1}$. Further 'top-ups' of 10 ml 0.25% bupivacaine were given as required throughout the remainder of labour. The mode of delivery, and the neonatal Apgar scores at 1 and 5 min were noted.

Statistical analysis was performed using Student's *t*-test, and the Mann–Whitney *U*-test as appropriate. Significance was accepted at the $p < 0.05$ level.

Results

Forty-nine patients were recruited into the study; 24 entered the saline group, and 25 the pethidine group. The two groups were comparable for age, weight, height, gestational age, cervical dilatation, and pain score prior to epidural catheter insertion (Table 1).

Of the 24 patients in the saline group, 18 (75%) patients

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Table 1. Demographic data. Values are expressed as mean (SD).

	Saline group (n = 24)	Pethidine group (n = 25)
Age; years	26.8 (4.1)	25.9 (5.8)
Height; cm	162 (4.8)	163 (4.4)
Weight; kg	65.9 (10.0)	69.2 (11.2)
Primiparous; %	75%	80%
Gestational age; weeks	40 (1.0)	40 (1.4)
Cervical dilatation; cm	3.7 (1.1)	4.2 (1.1)
Pain score prior to epidural insertion	70.6 (17.6)	67.0 (18.7)

Table 2. Effectiveness of epidural 30 min after bolus; number of patients (%).

Effect after 30 min	Saline group (n = 24)	Pethidine group (n = 25)
Satisfactory analgesia	18 (75%)	19 (76%)
Perineal pain	4	2
'Missed' segment	1	4
No noticeable effect	1	0

achieved satisfactory analgesia from the initial dose. Of the six other patients, three required a further 5 ml of 0.5% bupivacaine and one patient required 10 ml of 0.5% bupivacaine to achieve satisfactory analgesia. Two patients did not achieve adequate analgesia, one of whom had her epidural catheter resited.

Of the 25 patients in the pethidine group, 19 (76%) patients achieved satisfactory analgesia from the initial dose, two patients required a further 5 ml of 0.5% bupivacaine and two patients required a further 10 ml of 0.5% bupivacaine to achieve satisfactory analgesia. As in the saline group, two patients did not achieve adequate analgesia, of whom one had her epidural catheter resited (Table 2).

There was no difference between the groups in the time taken for the onset of analgesia, or in the pain scores following epidural insertion. However, the length of time between the initial dose and the first top-up injection was significantly longer in the pethidine group, $p < 0.001$ (Tables 3 and 4).

Tables 5 and 6 show the degree of motor blockade, incidence of side effects, and the mode of delivery in the two groups. The saline group experienced greater motor blockade than the pethidine group ($p < 0.05$). Patients in the pethidine group experienced a higher incidence of vomiting, and a lower incidence of shivering, compared to the saline group, although these differences did not reach statistical significance. No patients in either of the groups suffered pruritus. There were no significant differences between the groups in the mode of delivery.

Table 3. Top-up requirement of patients who had satisfactory analgesia at 30 min. Values are expressed as mean (SD).

	Saline group (n = 18)	Pethidine group (n = 19)
Time to first painless contraction; min	15.2 (7.1)	12.8 (3.9)
Time to first top-up; min	87.5 (16.4) (n = 17)	*122.2 (23.3) (n = 15)

Four patients in the pethidine group delivered vaginally and one patient in the saline group underwent Caesarean section, before requiring a top-up. These patients are not included in the data for the time to first top-up.

* Pethidine group > saline group, $p < 0.001$.

Table 4. Pain scores following epidural insertion (0 = no pain, 100 = very severe pain). Values are expressed as mean (SEM).

Time after epidural completion	Saline group (n = 24)	Pethidine group (n = 25)
10 min	34.6 (5.4)	25.8 (4.6)
20 min	19.4 (4.7)	16.7 (3.8)
30 min	19.4 (5.0)	11.8 (3.4)
At time of 1st top-up	48.1 (5.5) n = 17	52.3 (5.5) n = 15

Table 5. Motor block 30 min after completion of epidural (4 = no motor block, 1 = complete motor block); number of patients.

Motor block	Saline group (n = 24)	Pethidine group (n = 25)
4	10	18
3	10	6
< 3	4	1

Saline group > pethidine group, $p < 0.05$.

Table 7 shows the neonatal Apgar scores at 1 and 5 min. There were no significant differences between the groups. One neonate in the pethidine group had an Apgar score of only 2 at 5 min and required ventilation. The epidural had been in position for 10 h and the patient had failed to progress in labour, severe fetal distress then developed, requiring an emergency Caesarean section under general anaesthesia.

Discussion

Epidural pethidine, used alone or in combination with adrenaline, has been shown to be of value in labour, but its analgesic effect is unpredictable [7–9]. The combination of 25 mg of pethidine with 10 ml 0.125% bupivacaine used as the initial bolus dose and for subsequent top-ups has been reported as being very effective, with a high rate of patient satisfaction [10], but no previous study has compared a pethidine/bupivacaine mixture with plain bupivacaine for epidural analgesia in labour.

We have shown that the addition of 50 mg of pethidine to 9 ml 0.25% bupivacaine significantly prolongs the duration of epidural analgesia (from a mean of 87 min to a

Table 6. Incidence of side effects; number of patients. Mode of delivery; number of patients (%).

	Saline group (n = 24)	Pethidine group (n = 25)
Decrease in systolic blood pressure (> 20%)	4	0
Nausea only	1	0
Nausea with vomiting	1	4
Pruritus	0	0
Drowsiness	6	9
Shivering	8	1
Mode of delivery		
Spontaneous vaginal	13 (54%)	12 (48%)
Forceps	5 (21%)	3 (12%)
Ventouse	2 (8%)	4 (16%)
Caesarean section	4 (17%)	6 (24%)

Table 7. Neonatal data.

	1 min		5 min	
Apgar scores	Saline	Pethidine	Saline	Pethidine
9–10	15	10	24	23
7–8	8	10	—	1
5–6	1	4	—	—
< 5	—	1	—	1

mean of 122 min). Other opioids have been shown to prolong the duration of action of epidural bupivacaine in labour. Lirzin *et al.* showed that the addition of 80 μg of fentanyl to 12 ml 0.25% bupivacaine increased the mean duration of analgesia from 97 to 132 min [6], and Yau *et al.* showed that the addition of 50 μg of fentanyl to 10 ml 0.25% bupivacaine increased the mean duration of analgesia from 90 to 120 min [11]. Hunt *et al.* showed that the addition of 2 mg of butorphanol to 9 ml 0.25% bupivacaine increased the mean duration of analgesia from 59 to 137 min [4], and Phillips showed that the addition of 20 μg of sufentanil to 7 ml 0.25% bupivacaine prolonged the duration of analgesia from 90 to 137 min [5]. Diamorphine/bupivacaine mixtures have also been shown to produce superior analgesia to bupivacaine alone [3]. We have shown that pethidine prolongs the duration of analgesia to a similar extent. However, studies have also reported that some opioid/bupivacaine mixtures can increase the speed of onset of the epidural block [1,2,4,5], and improve the quality of analgesia [1,2], but we saw no evidence of such effects with pethidine.

A previous study reported that the addition of pethidine to epidural bupivacaine reduced the incidence of shivering [12]. Although not reaching statistical significance, we saw a similar effect, with only one patient in the pethidine group experiencing shivering compared to eight in the saline group. No patients in this study experienced any pruritus, which can affect 25% of patients given epidural fentanyl and up to 70% of patients given epidural diamorphine [3,6].

In conclusion, the addition of pethidine to bupivacaine given epidurally in labour is effective in prolonging the duration of analgesia, and is associated with a low incidence of pruritus. Pethidine does not increase the speed of onset or improve the quality of analgesia.

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The effect of music on ketamine induced emergence phenomena

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Summary

The purpose of this investigation was to assess the influence of music on emergence phenomena after ketamine anaesthesia. Fifty ASA 1 patients undergoing minor gynaecological procedures were randomly divided into two equal groups. Patients in the treated group were played music of their choice through headphones from 5 min before induction of anaesthesia to 15 min postoperatively. Although the incidence of emergence phenomena was similar in both groups the effects tended to be more pleasant and acceptable in those to whom music was played. The majority of patients in the study group (80%) expressed their willingness to have a similar anaesthetic in the future compared to 52% in the control group ($p < 0.05$).

Key words

Anaesthesia; dissociative.
Anaesthetics, intravenous; ketamine.
Complications; emergence delirium, emergence phenomena.
Music.

Since its introduction in 1965 [1] ketamine has been used extensively for various surgical procedures. Its use is associated with a high incidence of unpleasant emotional reactions and vivid dreams both in the recovery room and occasionally for long periods afterwards [2–4]. The reported incidence varies from 5 to 60% [3, 5] and is dependent on age, dose, concomitant medication, the extent of postoperative stimulation and other factors. Droperidol [6] and the benzodiazepines have been used to modify these unpleasant effects although their effectiveness is sometimes disputed [5, 7]. The likelihood of unpleasant emergence reactions is also said to increase if the surgical procedure is psychologically stressful [5] and recently viewed horror films or involvement in an accident can influence the nature and content of emergence phenomena [8, 9]. The present study was undertaken to observe the effects of perioperative music on the nature and incidence of ketamine-induced emergence phenomena.

Methods

Fifty women graded ASA 1, aged 25–45 years, not taking any medication, and scheduled for short gynaecological procedures were divided randomly into two equal groups. Patients with a psychiatric history were not studied. The study was approved by the hospital Ethics Committee and informed consent was obtained from all patients after explanation and reassurance [10]. All were premedicated with morphine 0.15 $mg.kg^{-1}$ and promethazine 0.4 $mg.kg^{-1}$ intramuscularly 1 h before operation.

After venous cannulation, headphones were applied to all the patients. The treated group were played music of their choice commencing 5 min before induction. The control group headphones remained silent. Ketamine (2 $mg.kg^{-1}$) was administered intravenously over 30 s to all the patients. Surgery commenced after 2 min and supplemental doses of 1 $mg.kg^{-1}$ were given every 10 min. The headphones were removed 15 min after the end of surgery.

Arterial blood pressure, pulse rate and electrocardiogram were monitored continuously during the operative period. None of the patients received any drugs postoperatively and all were left undisturbed during the recovery period.

On the second postoperative day patients were questioned about emergence phenomena as shown in Table 1. The responses were graded as either pleasant or unpleasant and patients were asked if they would like the same anaesthetic on a future occasion. In order to avoid observer error the assessments were made by the same investigator (A.K.) who was unaware as to whether or not music had been played.

Data were analysed statistically using unpaired Student's *t*- and Chi-square tests. A probability value of < 0.05 was considered significant.

Table 1. Protocol for the assessment of emergence phenomena.

1. What was the first thing you remember after you got the injection in the operating room?
2. What was the last thing you remember happening when you went to sleep?
3. What was the first thing you remember happening when you woke up?
4. How did you feel when you first woke up?
5. Do you remember a dream or any other experience while you were asleep?
6. What did things look like?
7. What did you hear?
8. How did your body feel?
9. What were you thinking about?
10. What was the worst or best thing about your operation?
11. How do you think about the kind of anaesthetic given to you?
12. Would you like to have the same kind of anaesthetic again?

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Table 2. Patient details, dosage, and duration of surgery, mean (SEM).

	Control ($n = 25$)	Music ($n = 25$)
Age; years	29 (1.8)	32 (1.4)
Weight; kg	47 (1.1)	45 (1.2)
Total dose of ketamine; mg	145 (3.1)	152 (3.6)
Duration of surgery; min.	21 (1.3)	23 (1.8)

Table 3. Patient acceptability of ketamine anaesthesia.

	Acceptable	No opinion	Not acceptable
Control group ($n = 25$)	13	4	8
Music group ($n = 25$)	20	4	1

Results

Patients' age, weight, ketamine dose and duration of surgery were similar in both groups (Table 2). The incidence of emergence phenomena was slightly higher in those listening to music (56%) compared to the control group (36%) but this was not statistically significant. In contrast, eight patients in the control group had unpleasant or horrifying dreams compared to three in the treated group, and one in the control group had pleasant dreams compared to 11 in the treated group. Unpleasant dreams were reported as sensations of choking, drowning, falling, floating and being trapped, whereas dancing, laughing and being very relaxed were recorded as pleasant.

Patient acceptance of ketamine anaesthesia is shown in Table 3. A high proportion in the music group would accept a similar anaesthetic again whereas the control patients found it less acceptable ($p < 0.05$).

Discussion

Emergence from ketamine anaesthesia in the postoperative period may be associated with visual, auditory, proprioceptive and confusional illusions which may progress to delirium [7, 11]. The dreams frequently have a morbid content and are often experienced in vivid colour.

Emergence phenomena probably occur secondary to ketamine-induced depression of the inferior colliculus and medial geniculate nucleus, leading to misinterpretation of auditory and visual stimuli [7]. Furthermore, the loss of skin and musculoskeletal sensation results in a decreased ability to perceive gravity and creates a sensation of bodily detachment or floating in space [12].

In the present study the overall incidence of emergence phenomena was 46% which is similar to that reported by other workers [5, 11, 13]. Music did not significantly alter the incidence of emergence phenomena but it seemed to improve the quality of emergence. Whether this is a non-specific response to auditory stimulation or a specific response to music is unclear.

In conclusion, the findings suggest that, although music during ketamine anaesthesia did not significantly alter the incidence of emergence phenomena, both the quality of recovery and patient acceptability were enhanced.

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Predicting difficult intubation

Dr C.M. Frerk is to be congratulated on his paper 'Predicting difficult intubation' (*Anaesthesia* 1991; **46:** 1005–8), and the President of the Association of Anaesthetists of Great Britain and Ireland demonstrated perspicacity in awarding the prize for this paper. However, as with most human endeavour, the paper is not perfect, but Dr Frerk has done good work and his publication is timely. If those of our colleagues who at present 'rely on predicting difficult intubation mainly as a result of the impression gained from the end of the bed' were to adopt his suggestion, many patients lives would be saved.

Some anaesthetists use different combinations of predictors e.g. Wilson *et al.* [1] but I prefer a combination based upon tongue size, head extension, chin size, mouth opening and mandible subluxation. Although it has to be independently confirmed, so far Dr Frerk's combination appears to be the best available (Table 1) from those published. The important thing is that all anaesthetists take the trouble to use a set of predictors and examine each patient for likely difficulty of intubation. Dr Frerk accepts (as we all must) that no screening test will be 100% sensitive, and that they will all have a number of false-positive results. It is up to

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Table 1. A comparison of the sensitivity, specificity and positive predictive value of the Frerk method of predicting difficult tracheal intubation with other methods for which these statistics have been published.

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)
Frerk method according to Frerk*	75	95	20
Wilson Risk sum according to Wilson *et al.* [1]	75	87.9	8
Wilson Risk sum according to Oates *et al.* [2]†	40	95	13
Mallampati method [3] according to Oates *et al.* [2]†	50	92	10
Mallampati method [3] according to Frerk*	75	79.2	5.7

*Figure recalculated by Bellhouse, deeming Cormack & Lehane [4] Grades III and IV patients to be difficult intubation and Grade II patients to be easy, to allow comparison with Oate's and Wilson's figures.

†Using the figures from Oate's observers 1–3.

practising anaesthetists to use one of the combinations of tests available, accepting the deficiencies, and changing the combination if a superior combination becomes available.

When a patient is predicted to be difficult, appropriate arrangements can be made regarding the scheduling of the patient for surgery, and for the mobilisation of appropriate skills and equipment. In this regard, the flexible fibreoptic laryngoscope, the Bullard laryngoscope [5, 6], or the Belscope angulated laryngoscope [7] may be considered. Each of these three laryngoscopes has its own particular characteristics, different technique of use, and different indications.

Some of our colleagues may point out that the majority of Dr Frerk's difficult cases were Cormack and Lehane Grade 2 and therefore susceptible to the Macintosh method [4, 8] of intubation. However, the point is that at the time of intubation the anaesthetist involved considered the patient difficult, and in other circumstances, where mortality is involved death resulted because the anaesthetist at the time found intubation difficult, no matter what anyone else at any other time might have done. When he says 'worldwide up to 600 people are thought to die each year from difficulties with intubation', Dr Frerk mis-states one of the references from an excellent review by Drs King and Adams [9] diminishing its import. He also says 'head extension is thought to be another factor of importance in determining the ease or difficulty of intubation', whereas King and Adams are quite clear when they give three references for their conclusion that 'inability to extend the head at the atlanto-occipital joint is an important cause of difficult intubation'. These, however, are only small flaws in what is a valuable paper.

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Trimeprazine premedication in children

Like Dr Zorab (*Anaesthesia* 1991; **46:** 1088) we are also concerned that the manufacturers of trimeprazine have reduced the maximum recommended dose to 2 mg.kg^{-1}. Their decision apparently has the support of the licensing authority and is likely to have medico-legal implications. It is perhaps even more worrying to learn from the manufacturers that they claim not to know how the original recommended dosage was arrived at. One of us (W.J.G.) was involved in the introduction of trimeprazine into clinical practice as an oral premedicant for children, and the original paper [1] compared its effect with a commonly used barbiturate (quinalbarbitone), in 200 children. The dose used was 2 mg.lb^{-1} (4.4 mg.kg^{-1}) and no untoward effects were reported. Following the original paper trimeprazine rapidly found general acceptance and has been widely used for more than 30 years. Although Bramwell and Manford [2] studying behaviour in the anaesthetic room and restlessness after operation in 192 children found no difference between 2 mg.kg^{-1} and 4 mg.kg^{-1} they did not report any adverse side effects with the higher dose. The authors of this paper had the advantage of a quiet pre-anaesthetic holding area adjacent to the operating theatre which is not available in many busy hospitals. Davies and Doughty [3] in a study of 484 children found a higher incidence of amnesia when 4.4 mg.kg^{-1} was used compared with 2.2 mg.kg^{-1}, with fewer children remembering the intravenous induction as an unpleasant experience. Although they noted an increase in the incidence of postoperative pallor with the higher dose, they did not attempt to assess its effect on blood pressure.

Apart from two anecdotal and apparently unpublished cases of cardiovascular collapse quoted by the manufacturers, their decision to reduce the maximum recommended dose is based on two publications. The first [4] reports respiratory depression in two siblings in whom trimeprazine was given for sedation after cleft lip or palate surgery. One child aged 3 months was given

2.4 mg.kg^{-1} and the second, his 3-year-old sister, 2.9 mg.kg^{-1}. In both of these cases there may have been an element of upper airway obstruction which was worsened by the sedation. Few would recommend the use of trimeprazine for night sedation in a child of 3 months even without upper airway obstruction. The second paper [5] describes four children who developed hypotension and bradycardia after premedication with trimeprazine (2.7–4.2 mg.kg^{-1}). All these children had pre-existing upper respiratory tract infection or fever and two had complained of abdominal pain before the onset of cardiovascular depression. The authors admit that in two of the cases the episodes were probably partially self-induced by posture and all four children made a complete recovery.

Phenothiazines have been implicated in the sudden infant death syndrome and it would seem wise to avoid their use in the first few months of life. In older children, however, the degree of sedation varies considerably from child to child and it is our opinion that a maximum dose of trimeprazine of 2 mg.kg^{-1} is often inadequate. We are not convinced by the evidence that higher doses are unsafe, and although we understand the manufacturers' desire to protect themselves we strongly recommend that the previously used dose range of 2–4 mg.kg^{-1} be reinstated.

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Opisthotonus and propofol

There have been several published reports where propofol administration has been associated with opisthotonus, but this phenomenon has usually occurred during the postoperative period [1–3]; there is only one case of opisthotonus occurring at induction of anaesthesia [4]. Although propofol may well have been the cause, other drugs had been administered concurrently. In one of these cases [3] the patient was an epileptic. It has subsequently been recognised by the Committee on Safety of Medicines that propofol should be used with care in patients with epilepsy [5]. We wish to report a patient in whom opisthotonus occurred at the time of induction of anaesthesia, when propofol was the sole drug administered.

A 5-year-old boy was admitted as a day case for myringotomy and grommet insertion. He was fasted for 6 h pre-operatively, and had no significant medical history apart from recurrent otitis media. Specifically, there was no history of convulsions, head injury or neurological disorder. He was not receiving any concurrent medication and no premedication was given. EMLA cream had been prescribed, but due to a nursing oversight, had not been applied. A 22 g cannula was inserted in a vein on the dorsum of the hand, and propofol 50 mg (3.13 mg.kg^{-1}) was administered during approximately 10 s. Immediately after the propofol had been given, writhing movements of the left hand and arm were seen, and a few seconds later, both hands and arms adopted a decorticate posture, being fully extended and pronated. A period of opisthotonus ensued which lasted approximately 20 s. During this time the whole body was arched in an extended position, the facial muscles were in spasm, and a degree of laryngeal spasm was evident. Halothane in 100% oxygen was administered by face mask as the muscle tone diminished and respiration commenced. The operation then proceeded as planned. Recovery from anaesthesia was uneventful, and no neurological abnormality was evident.

We postulate that the only cause for opisthotonus in this patient was the administration of propofol.

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Abnormal movements following recovery from propofol, alfentanil and nitrous oxide anaesthesia

We wish to report an incident of abnormal limb movements in a conscious patient following anaesthesia which included the use of propofol.

A 76-year-old man underwent anaesthesia for a check cystoscopy for a previously resected bladder tumour. He had a history of mild pulmonary aspergillosis and his regular medication was inhaled salbutamol and ipratropium bromide with oral prednisolone 2.5 mg daily. At the time of his initial tumour resection, he received a spinal anaesthetic from which he subsequently developed a severe postdural puncture headache requiring an extradural blood patch. Two subsequent cystoscopies, performed under general anaesthesia, were uneventful. Neither involved the use of propofol.

On the occasion we are reporting, premedication consisted of inhaled salbutamol 2 puffs and hydrocortisone 100 mg intravenously pre-induction. No sedative or antiemetic drugs were given. General anaesthesia was induced with propofol 150 mg and alfentanil 250 μg. The patient breathed 66% nitrous oxide in oxygen via a Bain system. Increments of propofol and alfentanil were given to maintain anaesthesia, to total doses of 350 mg and 1 mg respectively. No volatile anaesthetic agent was used. The procedure lasted approximately 30 min and involved minimal superficial tumour resection. The intra-operative period was unremarkable; the patients cardiovascular system remained stable and $S\text{po}_2$ was never less than 96%. At the end of the procedure the patient was taken to the recovery unit and was awake on arrival.

Approximately 10 min after recovery of consciousness, the patient developed jerking movements of all four limbs. There was no ocular muscle involvement. He remained fully conscious and lucid throughout and complained of inability to control these movements. The involuntary movements had not subsided within 10 min and he was then given intravenous procyclidine 5 mg. The movements stopped 10 min later. Following a further 20 min of uneventful recovery he was returned to the ward and was discharged from hospital the following day, as planned, with no residual effects. The involuntary movements noted were not classically extrapyramidal in nature and did not stop until 10 min after receipt of procyclidine. There must, therefore, be doubt as to the role of procyclidine in their abolition.

Abnormal limb movements have been noted on several occasions to be associated with the use of propofol [1] and this subject was reviewed in detail recently [2]. Grand mal convulsions have also been reported [3]. Following a literature search and discussion with the manufacturers of propofol, we believe this to be the first report of involuntary movements in a patient who had regained consciousness and who remained fully conscious.

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Use of propofol to terminate generalised myoclonus

The role of propofol in provoking epileptiform seizures is controversial. We would like to report the case of a patient with severe myoclonus, which was treated successfully with propofol.

A 69-year-old woman was transferred from another hospital for further investigations and treatment of a pyrexia of 40°C, generalised myoclonus and an encephalopathy. An EEG showed no focal features during the myoclonic episodes and routine investigations, including serum electrolytes and calcium, revealed only a raised white cell count. Three days after admission she developed a chest infection and required ventilation. Nursing care was virtually impossible due to the development of severe myoclonus at the slightest stimulus. A variety of anti-epileptic drugs, including diazepam and clonazepam, failed to resolve the myoclonus. A bolus of 30 mg of propofol dramatically stopped the seizures, and an infusion of propofol was started at $200\ \mu g.kg^{-1}.min^{-1}$. This allowed nursing care to continue without provoking the myoclonus, which returned if the propofol was stopped. The patient was commenced on sodium valproate therapy which eventually controlled the myoclonus, allowing withdrawal of the propofol. She returned to the ward with a diagnosis of a viral encephalopathy.

Numerous cases of central nervous system (CNS) excitability have been reported where propofol has been implicated as the causative factor [1–3], and the Committee on Safety of Medicines issued a warning on the risk of seizure activity following propofol administration [4]. In contrast, many studies dispute this proconvulsant activity. Using the cerebral function analysing monitor, Yate *et al.* [5] failed to discover an epileptogenic effect of propofol, and Dwyer *et al.* [6] demonstrated that the duration of seizure activity following electroconvulsive therapy was shorter following induction with propofol as compared to methohexitone. Propofol has been used successfully in the treatment of status epilepticus and in patients with CNS irritability [7]. The drug is recognised as causing an isoelectric EEG and it is possible that in this patient myoclonus was terminated secondary to generalised CNS depression. Unfortunately, an EEG was not performed on this patient during propofol sedation.

This case report illustrates the efficacy of propofol in controlling severe myoclonus.

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Another modification of the oesophageal detector device

The oesophageal detector device desccribed by Wee [1] and modified by Nunn [2] has been shown in a number of studies [3, 4] to be a sensitive and specific method of detecting or excluding oesophageal intubation. We decided to adapt further the device described by Nunn. Rather than an Ellick's bulb attached to a Nosworthy adaptor, we used the bulb of a disposable catheter-tip bulb syringe (Sherwood Med. Ind. Ltd), which makes a remarkably airtight fit with a standard disposable catheter mount. This has the slight advantage of being rather lighter, and also moves the bulb well away from the end of the tracheal tube. The device is used in the same way as that of Nunn; a single squeeze of the bulb is made with the tube in place and connected to the device, with rapid re-inflation indicating tracheal placement, and poor re-inflation indicating oesophageal placement or an obstructed tube.

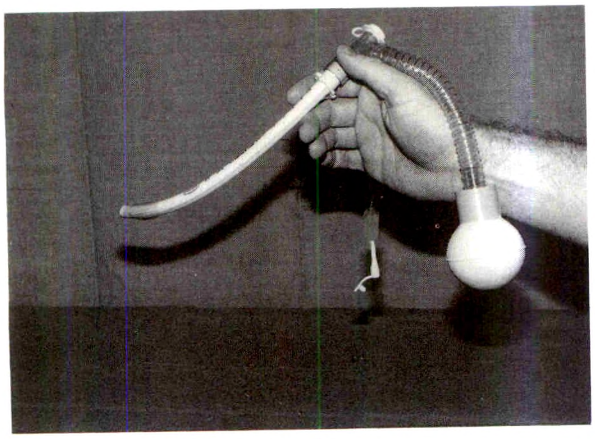

Fig. 1.

In the studies mentioned above, the devices in question were connected to the tube after intubation. This seemed to us to be unnecessarily slow. Using our version of the device, it was found to be easy to attach the device to the tracheal tube before intubation (Fig. 1), with minimal impediment to routine intubation, after a brief period of accustomisation (two to three intubations). In this way, intubation could be immediately followed by testing for correct placement in a single, rapid, one-handed movement.

One of us (P.L.), then a relative novice in anaesthesia, used the device in 172 consecutive intubations, excluding obstetric cases. His experience agreed in general with that of previous authors: 167 intubations were 'definitely' tracheal, with brisk re-inflation; on five occasions refilling was delayed and auscultation revealed endobronchial intubation (twice), or partial blockage by secretions (twice); on the other occasion oesophageal intubation was identified and corrected immediately.

The device was not used for obstetric cases for two main reasons. Firstly, it was felt that in these cases even minimal distraction during intubation was undesirable, although this would not have been a problem after a few weeks of use of the device. Secondly, having the device attached prior to intubation would delay the use of the gum-elastic bougie should intubation prove difficult. These problems could be overcome easily by a few weeks' practice (at most), and by having a second tracheal tube of the same size ready for use with the bougie, respectively.

Use of the device in this way has proved simple and can be recommended as a routine practice, including in obstetrics, the latter especially in view of reports suggesting that unrecognised oesophageal intubation is the single largest cause of anaesthesia-related deaths [5].

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Potential occlusion of the BOC Mk4 circle absorber

Breathing systems occluded by foreign bodies have been the subject of many reports. During workshop maintenance for an independent problem a BOC Mk 4 circle absorber revealed the presence of a mica unidirectional valve disc in the expiratory/spill valve chamber within the absorber head (Fig. 1). The disc was completely occluding one of the two outlet ports from this chamber that leads to the absorber on/off control cylinder. Moisture in the expiratory gases had caused the disc to become adherent through surface tension. (The valve assemblies contained two mica discs in their correct operating positions.) With the absorber lever in the 'off' position, the circle system would work normally. However in the 'on' position, gases would be prevented from entering the absorber and would only pass directly through the spill valve into the scavenging system. This converts the system to function not as a circle but as a nonreturn 'Mapleson A' system. This arrangement would work as long as the fresh gas flow remained greater than the patient's minute volume. Indeed this must have been the case when the last anaesthetist used the system because reduction of the fresh gas flow would have caused the reservoir bag to collapse.

At the end of each operating list the flexible breathing tubes are removed from the absorber and cleaned. The unidirectional valve discs are also removed, cleaned and dried before re-assembly. During this manoeuvre a disc could easily be dropped accidentally through the semicircular slot behind the valve cage and into the absorber head. On this occasion nobody could remember losing a disc during cleaning or re-assembly, and it is not known how long the disc had lain within the chamber.

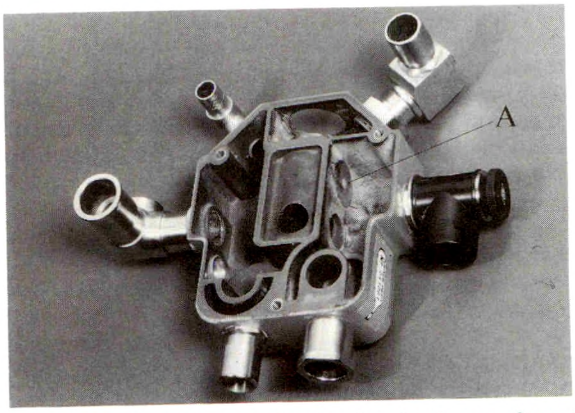

Fig. 1. The BOC Mk 4 circle absorber head seen from its underside. 'A' indicates the mica disc occluding the orifice connecting the expiratory/spill valve chamber and the on/off control cylinder.

The mark 5 absorber produced at present by BOC has a totally redesigned head block which prevents a mica disc entering its inner chambers. However, there are a very large number of mark 4 models in use which have many years of working life left. A little extra vigilance when handling mica discs would prevent this problem recurring. Most importantly, a 'lost' mica disc just may be inside the breathing system.

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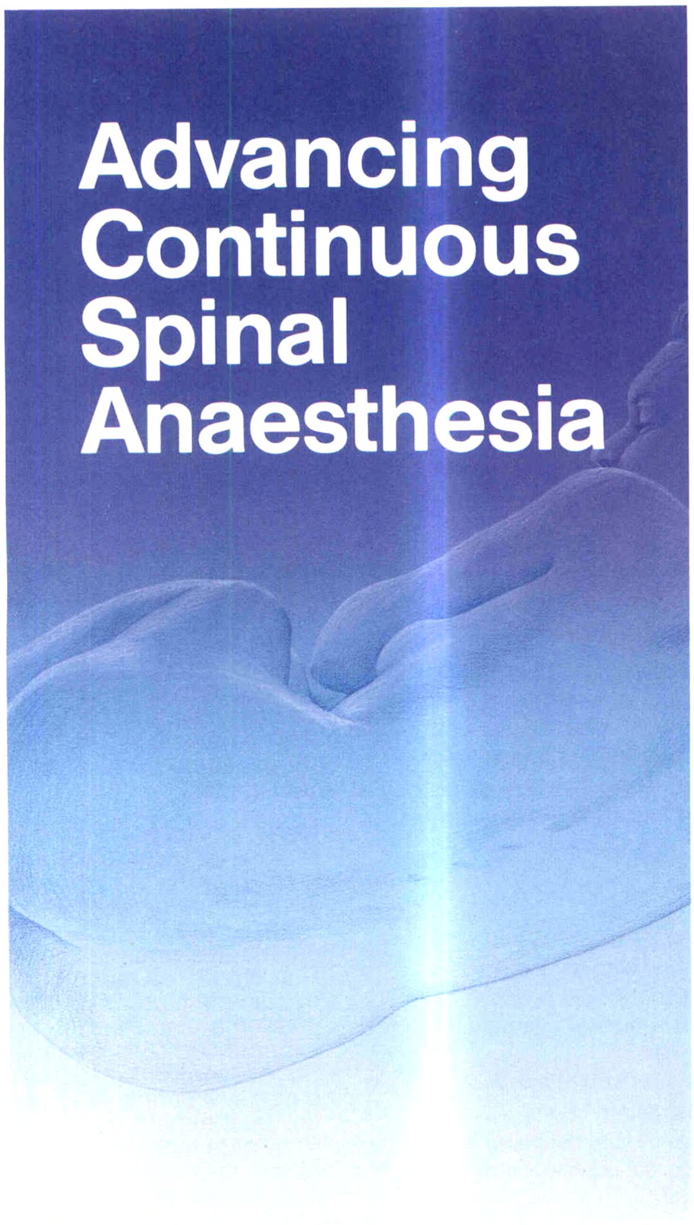

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Post-thyroidectomy vocal cord examination by fibreoscopy aided by the laryngeal mask airway

Because of potential damage to the recurrent laryngeal nerve during thyroidectomy, it is usual for the anaesthetist to look at the vocal cords at the end of the procedure to assess movement. The reported incidence of nerve damage varies from 0–8%, but this may be an underestimate due to difficulties with laryngoscopy [1]. The latter is often cursory due to light anaesthesia and is often accompanied by coughing.

We have recently been using a laryngeal mask airway to aid fibrescopic laryngoscopy at the end of thyroidectomy. Neuromuscular block is reversed and anaesthesia maintained with 50% nitrous oxide in oxygen with 0.5% isoflurane or enflurane. When spontaneous ventilation is established, the tracheal tube is removed and an LMA passed (size 3 for females and 4 for men). From this point onward the patient breathes 100% oxygen with 0.25–0.5% of isoflurane or enflurane. A flexible fibreoptic intubating bronchoscope can be introduced through the LMA, and in over 95% cases, the vocal cords were clearly visualised as the tip of the fibrescope emerged from the distal end of the LMA. Vocal cord movement could be demonstrated to junior staff members and surgical colleagues. Once the examination is over, the inhalational agent is withdrawn and the LMA removed when the patient is almost awake. This takes 5–10 min from the point of cessation of administration of the inhalational agent. During this entire period, electrocardiography, heart rate, blood pressure, tidal volume, oxygen saturation and end tidal CO_2 are closely monitored.

Use of a flexible fibreoptic instrument without the help of the LMA requires an experienced operator and often takes some time; there is often a considerable increase in blood pressure and heart rate [2]. When an LMA is used relatively little expertise is required, as the shape of the mask automatically guides the fibrescope towards the vocal cord.

The technique described provides an excellent view of the vocal cords, minimal haemodynamic changes, a secure airway and relatively quick recovery on withdrawal of the inhalational agent.

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The laryngeal mask airway and intra-ocular surgery

We read with some concern the paper by Holden *et al.* (*Anaesthesia* 1991; **46:** 922–4), which described the use of the Brain laryngeal mask airway (LMA) for elective intermittant positive pressure ventilation during ophthalmological surgery whilst the patient was paralysed with a nondepolarising relaxant.

Although the LMA has been used successfully in many trials in this manner, including in the original description by Brain [1], it has been shown that an airtight seal cannot be reliably formed in all patients under these circumstances. Furthermore, it has been shown in other studies [2, 3] that the pressure needed to create a significant leak around the airway in patients whose lungs are being ventilated is only 2 kPa. One of the potential consequences of this leak is the risk of aspiration of stomach contents, a scenario which has been reported and discussed in this journal fully in recent editions [4, 5]. This has led to the manufacturer's recommendation that the apparatus should not be used where there is a potential risk of aspiration. There is also the danger of inflation of the stomach with anaesthetic gases. This gastric distension intra-operatively may lead not only to an increased risk of aspiration but also to an increase in postoperative vomiting which will in turn cause the intra-ocular pressure to rise [6].

Therefore, we believe that despite the recommendations of Holden *et al.*, the use of intermittant positive pressure ventilation via the LMA for intra-ocular operations is not an ideal method of anaesthesia, and should be used with great circumspection in this as well as all other surgical fields.

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We read with interest the paper by Holden *et al.* (*Anaesthesia* 1991; **46:** 922–4) regarding intra-ocular pressure (IOP) changes using the laryngeal mask airway (LMA) and tracheal tube. However, we would like to raise a number of points.

Although the authors imply otherwise, there is in fact a well documented pressor response to LMA insertion [1, 2]. It is conceivable that this could be affected by the degree of pharyngeal distension, which might in turn influence IOP. It would therefore be interesting to know the size of LMA used, and the volume of air used to inflate the cuff. Is it possible that pharyngeal distension might also affect the venous drainage of the head and neck, having implications for IOP?

We believe that the statement, 'postoperative coughing was significantly reduced using the laryngeal mask airway' should be qualified, as any study reporting incidence of cough should give data on patients' smoking habits. It is important that the authors confirm that airway removal took place at the same depth of anaesthesia in both groups, since any difference would influence the incidence of coughing in the first minute, and possibly also the IOP.

Finally, in recommending the LMA as an alternative to tracheal intubation in routine and emergency intra-ocular surgery the authors ignore the advantages in airway control offered by tracheal intubation. We believe that the LMA is more vulnerable to complete or partial displacement during surgery than a tracheal tube. Any subsequent airway compromise with the globe of the eye open, the head draped, and access to the airway restricted, could have serious consequences. During emergency surgery there may be the added hazard of a potentially full stomach with all its concommitant risks of aspiration. The LMA affords no airway protection in these circumstances.

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A reply

Thank you for the opportunity to reply. In our study we measured the immediate changes in intra-ocular pressure (IOP) in the two groups. We did not continuously measure the pressor responses and neither did Braude *et al.* [1], who measured changes at intervals of one minute. Hickey *et al.* [2] did continuously measure cardiovascular changes during LMA insertion, but were not comparing the pressor response with that of tracheal tube insertion. That there is a pressor response to LMA insertion is beyond dispute but use of the LMA would seem to attenuate this. However, to avoid confusion we should have cited these papers.

For the trial all males had a size four LMA and females a size three. Inflation volumes were approximately 30 ml of air in males and 20 ml in females. Increased pharyngeal distension resulting in an increased IOP response would seem unlikely, especially as we found a reduced IOP response in the LMA group.

Patients with any form of chest disease were not studied. We did not include a smoking history, random assignment of patients to each group should have negated the effect of this detail. However, with the relatively small numbers involved we agree a smoking history would have improved the power of the study. Removal of the LMA was performed at deeper levels of anaesthesia than usual in order to equate to those in the tracheal tube group. In either case the judgement of level of anaesthesia was based on clinical grounds along with use of the nerve stimulater. In the paper we did discuss the difficulties of blinding the anaesthetist to the type of airway used at this stage.

With regard to LMA displacement, it is the normal practice of the anaesthetists involved in the study to induce anaesthesia on the operating table. No further movement of the patient is required and further movement of the head is actively discouraged by most eye surgeons. This, together with the ease of assessing the integrity of the seal during placement of the airway, reduces greatly the risk of dislodgement. There have been over 400 intra-ocular procedures performed at the study centre using the LMA, without a single case of airway displacement. Ocular emergencies very rarely necessitate immediate anaesthesia, so delaying surgery to allow for gastric emptying is the usual practice, thus avoiding the well documented major risks involving use of the LMA. Use of the LMA remains a subject of considerable debate, and while many anaesthetists are using it their decision to continue to do so must be guided by potential advantages as well as disadvantages.

We would like the opportunity to point out an erratum. Anaesthesia was maintained using 0.5% isoflurane in oxygen and not 1.5% as stated in the paper.

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Laryngeal mask airway for radiotherapy in the prone position

Use of the laryngeal mask in anaesthesia for radiotherapy in children has been reported previously [1–3]. I report here its use in a 15 kg boy aged 2 years and 8 months who underwent cranial radiotherapy in the prone position for a posterior fossa medulloblastoma; treatment was carried out on 29 occasions, excluding weekends, over a 6 week period on an outpatient basis.

The patient had previously had a central venous line (Portacath) inserted for chemotherapy, but this had become infected and blocked and re-implantation of another was not considered advisable. It was decided to administer the anaesthetics using an inhalational technique and the laryngeal mask airway. The patient arrived fasted and unpremedicated for each treatment. Anaesthesia was induced with the patient on his father's knee using a volatile agent and 66% nitrous oxide in oxygen at a fresh gas flow of 6 $l.min^{-1}$ delivered via a Bain system. Halothane was used on the first few occasions, and subsequently isoflurane was used. When the patient was asleep he was placed supine. A size 2 laryngeal mask airway was inserted when sufficient depth of anaesthesia had been achieved. A head frame was then positioned and the patient was turned prone (Fig. 1). Anaesthesia was

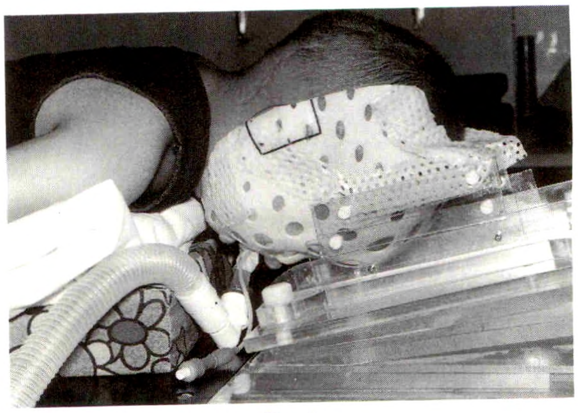

Fig. 1

maintained with 0.75% isoflurane and 66% nitrous oxide in oxygen. Padding was utilised under the chest and pelvis to allow diaphragmatic excursion. The patient was monitored by observation of the rebreathing bag and pulse oximetry. Throughout the procedure arterial oxygen saturation was maintained in the range 97–100%. A capnograph was used during one treatment, which showed end-tidal carbon dioxide concentration to remain below 6.6 kPa. It was necessary for all attendants to leave the room for several minutes for the actual administration of radiotherapy. During this time the patient, oximeter and rebreathing bag were viewed using closed circuit television.

Problems encountered included one episode of minor regurgitation during induction with no adverse sequelae, and two instances of difficulty in obtaining an adequate airway, rectified by altering the height of chest padding, and in one instance by removing and re-inserting the laryngeal mask. There were no instances of laryngeal spasm. Each anaesthetic lasted approximately 15 min. Recovery was rapid with the patient always able to be discharged within 15–20 min. There were no episodes of nausea or vomiting and no complaints of sore throat.

The laryngeal mask has already proved to be a useful adjunct to repeated anaesthesia for radiotherapy in children [1–3]. This case demonstrates its practicality and safety when a brief anaesthetic is required in the prone position. It provides a secure airway and facilitates monitoring of ventilation without the morbidity associated with repeated tracheal intubation.

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W.D. NGAN KEE

References

[1] TAYLOR DH, CHILD CSB. The laryngeal mask for radiotherapy in children. *Anaesthesia* 1990; **45:** 690.

[2] WAITE K, FILSHIE J. The use of a laryngeal mask airway for CT radiotherapy planning and daily radiotherapy. *Anaesthesia* 1990; **45:** 894.

[3] GREBENIK CR, FERGUSON C, WHITE A. The laryngeal mask airway in pediatric radiotherapy. *Anesthesiology* 1990; **72:** 474–7.

Complications of inhalational anaesthesia

The cross sectional study undertaken by Dr Lew, Professor Spence and Dr Elton (*Anaesthesia* 1991; **46:** 810–5) provides a fascinating picture of recent anaesthetic practice and the authors are to be congratulated, not only on the hard work involved, but also on the clear presentation of the evidence derived from so many data. I believe that the timing of their survey makes it particularly interesting, for I suspect that it precedes the adoption of the Brain laryngeal mask airway (LMA) as a common adjunct for spontaneous breathing of anaesthetics.

If one assumes that the 52.3% of cases who were not intubated were maintained on a facemask (with or without Guedel airway) these 8888 cases represent a repository of information on the complications associated with this mode of anaesthetic administration with which the introduction of the LMA for similar populations may be compared, when sufficient time has elapsed for matters of technique and case selection to have settled down.

Although the significant increase in a number of complications related to intubation versus nonintubation is noted, no separate incidences are quoted and subsequent comparisons will not be possible. Can one ask, therefore, for a further analysis of these data to record the rates of the various complications associated with nonintubated patients and with those intubated but breathing spontaneously?

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M.L. HEATH

Epidural needle rotation and inadvertent dural puncture with catheter

We routinely use the single segment, combined spinal–epidural technique for elective Caesarean delivery in our institution. A retrospective survey of 100 such consecutive procedures revealed a 3% incidence of inadvertent dural puncture with the epidural catheter. One of the factors responsible for this may have been our practice of maintaining the cephalad direction of the epidural needle bevel for both dural puncture with the spinal needle and epidural catheter insertion. Recent correspondence in this journal (*Anaesthesia* 1991; **46:** 802) recommended rotation of the Tuohy needle through 180° to avoid inadvertent dural puncture with the epidural catheter.

We followed this recommendation and present data of a prospective survey of 30 combined spinal–epidural procedures for elective Caesarean delivery. The epidural space was entered using a 17 G Hustead needle with the bevel directed caudad and a long 25 G spinal needle introduced to perform subarachnoid injection of 0.75% bupivacaine in 8.25% dextrose. After completion of subarachnoid injection, the spinal needle was withdrawn and the epidural needle gently rotated 180° to face cephalad and the epidural catheter inserted. The findings are shown in Table 1.

To establish that the clear fluid was cerebrospinal fluid (CSF) and not the local anaesthetic injected, the criteria used were free flow, positive aspiration and siphon, Dextrostix and thiopentone tests. Although positive in each of our patients with clear fluid in the catheter, the Dextrostix test is unreliable because of the presence of dextrose in the bupivacaine solution. If the clear fluid is allowed to come in contact with a solution of thiopentone (pH 10), turbidity will occur immediately when the fluid is local anaesthetic (pH 5), but not when it is CSF (pH 7) [1]. In our survey, the clear fluid in the catheter in all five patients was confirmed to be CSF by all of the above tests.

Table 1. Use of the Tuohy needle in 30 spinal–epidural procedures.

	Before turning needle	After turning needle
Blood in the needle	0	0
CSF in needle	0	
Blood in catheter		2
Clear fluid in needle		1
Clear fluid in catheter		5

Interestingly, none of these patients developed a postdural puncture headache.

Our data suggest that during combined spinal–epidural procedures inadvertent dural puncture with the epidural catheter may not be prevented by rotation of the needle as recommended by Hughes and Oldroyd. As opposed to the blunt tip of the Tuohy needle, the straight, sharp tip of the Hustead needle may not angle away the epidural catheter from the dural puncture made by the spinal needle. This may have been responsible for the high incidence of dural puncture with the catheter in our survey. Other factors to consider are calibre and needle tip design of the spinal needle, the stiffness of the catheter and the experience of the operator. In our survey, the incidence of inadvertent dural puncture with the catheter increased from 3% to 17% with rotation of the epidural needle through 180°; hence, we have abandoned this practice in our institution.

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Reference

[1] Catterberg J. Local anesthetic vs. spinal fluid. *Anesthesiology* 1977; **17:** 309.

Disposable EMLA patches

EMLA 5% (Astra Pharmaceuticals Ltd) has revolutionised paediatric anaesthesia by making intravenous injections painless. It has not gained popularity in adults, although as many as 34% of adults express anxiety at the prospect of injections [1]. The present method of applying EMLA, squeezed from a tube and covered with an adhesive dressing, does not encourage its wider use. A simple alternative for us has been to use an EMLA patch at the time of premedication. Each was made from a disposable ECG electrode (Medicotest, Denmark) with the conductive gel removed and 0.5 ml EMLA on a piece of sponge put in its place (Fig. 1). Prepared patches were easy to carry, and were placed over an obvious vein during pre-operative visiting. In emergencies, there was occasionally little time for more formal preparation, but EMLA used topically for only 5 min has been shown to reduce significantly the amount of pain a patient is likely to experience during venepuncture [2]. We have found this method to be effective, convenient and, if made available on the wards, one which would be preferred by our nursing staff.

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J.S. Anwari
M.R. Nott

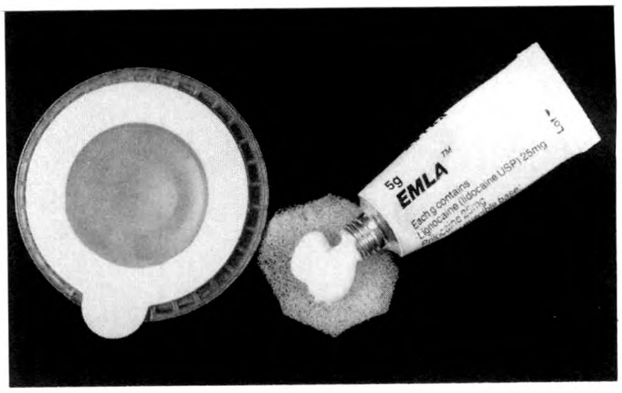

Fig. 1.

References

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[2] Nott MR, Peacock JL. Relief of injection pain in adults. EMLA cream for 5 minutes before venepuncture. *Anaesthesia* 1990; **45:** 772–4.

Performance of the Datex infrared anaesthetic agent monitor

We were interested to read the paper by Foley and colleagues (*Anaesthesia* 1990; **45:** 232–4) describing the quantitative effect of blood alcohol on the performance of the Datex Capnomac for infrared measurement of concentrations of volatile anaesthetic agents.

We would like to draw your readers' attention to another source of error experienced when using the Datex infrared anaesthetic agent monitor for measuring expired halothane concentrations in herbivores. Tayor [1] described abnormally high expired halothane readings during halothane anaesthesia in horses and sheep and reported readings from expired gases of up to 0.8% halothane obtained when no volatile agents were in use. Moens and colleagues [2] identified the problem as methane, which is expired in varying amounts by herbivores. They demonstrated that, as the Datex analyser measures absorption at 3.3 μm wavelength, interference from methane, which has a large absorbance peak at this wavelength, can be expected. They also demonstrated that infrared equipment using a higher wavelength (10.3–13 μm) (Anaesthetic Gas Monitor AGM 1304) was not subject to the same interference and gave an accurate record of end-tidal halothane and isoflurane.

We should like to report that, in our experience, anaesthetic agent monitors based on a piezo-electric crystal (Lamtec and Kontron) have proved to be unaffected by nonanaesthetic gases expired by herbivores. We have anaesthetised both sheep and horses with intravenous agents alone and zero concentrations of halothane and isoflurane have been recorded by such equipment throughout several hours of anaesthesia. End-tidal concentrations recorded throughout clinical halothane anaesthesia in both species have been compatible with reported MAC values for these species but we have not made simultaneous comparison with any other recording equipment.

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Hatfield, Herts AL9 7TA

K.W. Clarke

References

[1] Taylor PM. Interference with the Datex Normac anaesthetic agent monitor for halothane in horses and sheep. *Journal of the Association of Veterinary Anaesthetists* 1990; **17:** 32–5.
[2] Moens Y, Gootjes P, Lagerweij E. The influence of methane on the infrared measurement of halothane in the horse. *Journal of the Association of Veterinary Anaesthetists* 1991; **18:** 4–7.

Potential overestimation of blood loss into disposable suction apparatus

The use of closed disposable suction units has recently increased in an attempt to reduce the potential for cross infection. A variety of systems are available and we wish to report our observations with the East Healthcare Ltd system. The possibility of inaccurate estimation of suction volume became apparent when assessing the volume of blood aspirated during total hip arthroplasty. The disposable suction apparatus consisted of a strong, flexible, plastic bag with printed volume gradations, suspended in a rigid plastic container. Both were supplied by East Healthcare Ltd. With the bag suspended in its holder under vacuum conditions, the calibration on the disposable plastic bag indicated a volume of 1200 ml. However, when the bag was removed from its holder and placed on a flat surface the volume had apparently increased by 100 ml due to the change in shape of the bag.

To investigate this further, 1 l of water (weight 1 kg on an electric scale) was poured into the East Heathcare suction bag. Consistent readings of 1.2, 1.3 and 1.2 l were obtained respectively with the bag in its rigid container with vacuum applied, suspended in air outside the container and resting on a hard surface. This demonstrates a potential for 20% overestimation in volume of blood loss, which was confirmed when the test was repeated with 0.5 l of water, measured under the same conditions.

Using this suction apparatus could therefore lead to the possibility of error.

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Bristol

D. Marsh
D. Coates

A reply

In reply to D. Marsh and D. Coates' letter regarding the East Healthcare Disposable Suction Liner we comment as follows.

The liner is calibrated for use while installed in the jar and under vacuum. We accept the comments in the published letter and have, to avoid confusion, modified the instructions on the liner peel pouch wrapper. As part of our continued development programme we are currently printing a dual scale on the liner. We expect this work to be completed within the next 6 months.

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J.P. Bennet

Patient controlled analgesia machines — competitive tendering

With the great interest and widespread development of acute pain services in the United Kingdom, the clinical use of patient controlled analgesia (PCA) machines has seen a rapid upsurge. Unfortunately, as is all too common, the 'ideals' of such a service development are not always met by the necessary NHS funding.

During the development of an 'Acute Pain Service' in 1990 at the Northern General Hospital, Sheffield, a substantial charitable sum of money became available for the purchase of PCA machines. To choose the dedicated PCA machine manufacturer for this service, it was decided to 'trial', clinically, four of the currently available machines. The manufacturers were approached (Graseby, Bard, Ivac, and Abbott), and pumps were provided on loan for a 2-month period. Competitive tendering in the form of a 'Dutch auction' was held between the manufacturers and the authors during the 2-month trial period. This substantially reduced the prices of all pumps involved.

Taking into account the individual appraisals and the written tenders from the manufacturers, democratic opinion led to the purchase of multiple Bard PCA1 machines. We would now like to highlight the beneficial points from such an execise which could greatly assist other colleagues embarking on the purchasing of PCA machines: (1) competitive tendering in the form of a dutch auction reduced substantially the prices (greater than £1200 per pump!); (2) the tendered manufacturers backup services were varied, and in some cases quite extensive; (3) two manufacturers also offered consumables at very competitive prices; (4) multidiscipline 'hands-on' appraisal of several machines quickly highlighted problems and provided useful education without any capital expenditure.

It is important to emphasise that such a trial could only take place with close supervision and monitoring of the PCA machines on a 24 hourly basis. Education of all staff and patients involved, highlighting the principles of PCA, was a further prime objective. Specific in-service training for the individual pumps was left until the 'singular' choice had been made.

Surely, this style of purchasing has great applications for the developing 'NHS businesses'?

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E.A. Welchew

Extradural analgesia and previous spinal surgery — a radiological appraisal

Dr Calleja (*Anaesthesia* 1991; **46:** 946–7) has illustrated his paper with two very interesting radiographs. Figure 2 shows the spread of contrast medium to T_6. This spread of contrast relates to the spread of analgesia provided by the epidural, but it is claimed to be due to the previous surgery at the lumbar level preventing spread caudally. The X ray appearances shown are identical to those described as typical of a subdural injection of contrast medium [1]. Indeed many of us have reproduced these X ray appearances when performing subdural injections of neurolytic agents for cancer pain. It is well recognised that it is possible to inject into the space between the arachnoid and the dura in this way and that this does give a greater spread of contrast and local anaesthetic and often a higher analgesic level.

I would suspect that the reason for the high analgesic level was quite simply that the local anaesthetic entered the subdural space and that this was a subdural injection, in part at least.

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Reference

[1] Maher R, Mehta M. Spinal (intrathecal) and extradural analgesia. In: Lipton S, ed. *Presistent pain: modern methods of treatment,* Vol. 1. London: Academic Press, 1977: 61–99.

A scoring system for anaesthesia

I agree with Dr J.B. Glen (*Anaesthesia* 1991; **46:** 1081–2) that there is a need for a generally applicable system for scoring the quality of anaesthesia in spontaneously breathing patients. Such a system would be especially useful for those of us who wish to compare intravenous with inhalational techniques. It is important too that we concentrate on spontaneously breathing patients, as it is very easy to mask many problems by the judicious use of relaxants and controlled ventilation.

I would, however, suggest that, instead of trying to aggregate the components to form a single score, we display the components individually. I also think that we should include a simple assessment of smoothness of induction. The final score might be a five digit number, scoring induction, movement, haemodynamic instability, ventilation and recovery, with each component scored from 0 (best) to 4 (worst). Perfection therefore would score 00000, and stormy anaesthesia with delayed recovery, 44444. The advantage is that a composite score may still be obtained if that is required, but the individual components may be weighted differently. Additionally, other investigators may extend the scoring system to add other dimensions, but the early digits would retain the same significance, and so valid comparisons could still be made.

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T.J. Mimpriss

Airway exchange catheter placement

The Cook airway exchange catheter has recently been introduced into clinical practice. This radiopaque device has an internal diameter of 3 mm and is used as a bougie to facilitate replacement of one tracheal tube with another. The major advantage over the standard gum-elastic bougie is that oxygenation may be resumed at any time during the procedure via a 15 mm adapter that locks into position at the proximal end of the catheter. Displacement of the catheter may occur and subsequent insufflation of the oesophagus would precipitate hypoxia and regurgitation. A means of distinguishing tracheal from oesophageal placement prior to insufflation would be of value.

We have investigated the use of Wee's oesophageal detector device [1] for this purpose in 20 patients. In each case tracheal and oesophageal placement were correctly differentiated. Carey *et al.* (*Anaesthesia* 1991; **46:** 1083) reported that correct placement of a hollow bougie-like introducer in the larynx could be confirmed by measurement of carbon dioxide efflux. We would advocate the oesophageal detector device as a suitable alternative.

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Reference

[1] Wee MYK. The oesophageal detector device. Assessment of a new method to distinguish oesophageal from tracheal intubation. *Anaesthesia* 1988; **43:** 27–9.

Pilo-erection and anaphylactoid/anaphylactic reactions

We read with interest the report by Drs Rabey and James of pilo-erection occurring as the first manifestation of an anaphylactoid reaction to the induction of anaesthesia (*Anaesthesia* 1991, **46:** 897–8). They stated that a literature search found no reports of pilo-erection associated with anaphylactoid or major drug reactions and concluded by posing the question, 'might pilo-erection be a useful warning of a potentially life threatening situation?' It is worth noting that a fatal anaphylactic reaction to suxamethonium in a 40-year-old woman was reported by Assem and Ling in this journal 3 years previously, in whom pilo-erection was noted within 90 s of induction of anaesthesia [1]. It is indeed possible that pilo-erection might be an early manifestation of anaphylaxis.

However, the mechanism for pilo-erection during an anaphylactic reaction remains unclear. It is possible that mediators released during mast cell degranulation, particularly the cysteinyl leucotrienes C_4 and D_4, which are known to be potent vasoconstrictors of both vascular and nonvascular smooth muscle [2], act directly upon the arrectores pili muscles causing pilo-erection. There may also be a compensatory initial increase in sympathetic tone during apaphylaxis resulting in pilo-erection mediated via the sympathetic postganglionic innervation [3] to the arrectores pili muscles.

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M. Scallan

References

[1] Assem ESK, Ling YB. Fatal anaphylactic reaction to suxamethonium: new screening test suggests possible prevention. *Anaesthesia* 1988; **43:** 958–61.

[2] Wilson JD, Braunwald E, Isselbacher KJ *et al*,. eds. *Harrison's principles of internal medicine,* 12th edn. McGraw-Hill Inc, 1991: 1422.

[3] Weiss L, ed. *Cell and tissue biology,* 6th edn. Baltimore: Urban and Schwarzenberg, 1988: 325.

Postpartum headache and cerebral tumour

We were interested to read Dr Dutton's case report of a 'postspinal headache' associated with incidental intracranial pathology (*Anaesthesia* 1991; **46:** 1044–6). We have recently seen a case of a cerebral neoplasm presenting as a postpartum headache.

A 22-year-old woman presented with a history of headache which had developed after the birth of her first child 2 weeks previously. Her confinement had been at a hospital in another region, epidural analgesia had been used and the delivery was by forceps. On questioning, she complained of a headache in the frontal and temporal regions which had developed 2 days after delivery and had become increasingly severe. Sitting up exacerbated the headache, and she had vomited during the 2 days before admission. The symptoms were thought to be consistent with an accidental dural puncture and an anaesthetic opinion was sought. She was orientated, and examination revealed no focal neurological signs, neck stiffness, photophobia or papilloedema. Her heart rate was 80 beat.min^{-1} and her blood pressure 105/60 mmHg. Full blood count and electrolytes were unremarkable. Further observation revealed that her headache was present at all times, even when lying supine. She was also pyrexial with an axillary temperature of 37.8°C.

The epidural form and obstetric notes were reviewed and no evidence of a dural tap found. The history was not typical of that following dural puncture. Observation was continued, blood cultures taken and she was given simple analgesics. She became disorientated and a computed tomography scan of the brain was requested. This showed obstructive hydrocephalus of the lateral ventricles with a mass in the midbrain and obliteration of the third ventricle. She was transferred to the regional neurosurgical centre for further management. The hydrocephalus was drained and the mass diagnosed as an astrocytoma.

This case illustrates a rare cause of postpartum headache and the importance of differentiation of symptoms. The epidural used for labour was initially implicated, but the history was not consistent with that following dural puncture.

Roelvink *et al.* [1] reviewed pregnancy-related, primary brain and spinal tumours and reported 223 patients where initial manifestation or acceleration of symptoms occurred during pregnancy itself, and 17 patients with initial symptoms in the first week postpartum. In 30 patients postpartum amelioration of symptoms occurred. In the recent triennial report on maternal deaths, three malignant neoplasms of the brain and one benign tumour were documented [2].

Cerebral neoplasm is rare, but should be considered in the differential diagnosis of postpartum headache. Dural puncture during an attempted blood patch in this woman might have precipitated fatal coning.

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Chester P.E. Pigston

References

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[2] Department of Health. Welsh Office. Scottish Home and Health Department. Department of Health and Social Services, Northern Ireland. *Report on confidential enquiries into maternal deaths in the United Kingdom* 1985–87. London: HMSO, 1991.

The pulse oximeter and Allen's test

Cannulation of the radial artery is a common procedure for intra-arterial blood pressure measurements. Although adverse effects due to impaired circulation following cannulation are rare [1], it is recommended that Allen's test [2] be performed in order to determine the adequacy of collateral flow from the ulnar artery. Allen's test is not always easy to do and interpret in an unconscious patient, in whom a pulse oximeter placed on a fingertip may be useful. When a pulse wave has been established on the display, firm pressure should be placed over the patient's radial artery. If there is still a wave form and an unchanged oxygen saturation reading from the pulse oximeter, ulnar collateral flow should be adequate.

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References

[1] Slogoff S, Keats AS, Arlund JC. On the safety of radial cannulation. *Anesthesiology* 1977; **47:** 37–9.

[2] Allen EV. Thromboangitis obliterans: methods of chronic obstructive lesions distal to the wrist with illustrative cases. *American Journal of Medical Sciences* 1929; **178:** 237–44.

Muscle damage with diclofenac injections

The recent letter by Drs Ali and Mathias highlighted the problem of muscle pain after injection of diclofenac sodium (Voltarol, Geigy), (*Anaesthesia* 1991; **46:** 1089). The authors have clearly identified an important difficulty which effectively restricts the use of this valuable analgesic in the postoperative period. It is important to know that there is evidence that intramuscular injections of diclofenac do produce muscle damage. In a volunteer study, intramuscular diclofenac was associated with significant increases in serum creatinine phosphokinase concentrations, but injections of buprenorphine or ketorolac (Toradol, Syntex), another injectable NSAID, were not [1]. In addition, clinical studies using ketorolac have shown that repeated intramuscular administration after surgery does not produce significant injection site pain or damage [2].

Muscle damage and pain after diclofenac is certainly a disadvantage of this preparation, but whether deep intramuscular injection, as recommended by the manufacturers, satisfactorily abolishes it is unclear. In the absence of clinical studies comparing diclofenac with ketorolac as intramuscular analgesics, it may be appropriate to prefer the latter for postoperative use.

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References

[1] MacDonald FC, Gough KJ, Nicoll RAG, Dow RJ. Psychomotor effects of ketorolac in comparison with buprenorphine and diclofenac. *British Journal of Clinical Pharmacology* 1989; **27:** 453–9.

[2] Power I, Noble DW, Douglas E, Spence AA. Comparison of i.m. ketorolac trometamol and morphine sulphate for pain relief after cholecystectomy. *British Journal of Anaesthesia* 1990; **65:** 448–55.

'Whoosh' test

I read with interest the article by Drs Lewis *et al.* (*Anaesthesia* 1992; **47:** 57–8) in which they describe a method to locate the caudal epidural space. Once the needle is correctly positioned, 2 ml of air are injected while auscultating with a stethoscope over the thoracolumbar area. Correct placement is confirmed by hearing a 'whoosh'. I would like to point out however, that I described an identical test some years earlier [1]. I am particularly indebted to Dr B.R. Puddy, Oldham Royal Hospital, who first introduced me to this test in 1983. Since that time, I have used this technique on many patients and like Drs Lewis *et al.*, have found it a useful confirmatory test of correct needle placement.

A modification of this test is the addition of a small amount of fluid to the air in the syringe. This amplifies the sound and converts it from a gentle 'whoosh' to a loud crunch.

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Reference

[1] LEE ME. Identification of the caudal epidural space. *Anaesthesia* 1988; **43:** 705–6.

I would like to thank Mr Mulholland and his team (*Anaesthesia* 1992; **47:** 57–8) for their acknowledgement to me for the description I gave to this test at the Spinal Meeting at Black Notley Hospital, Braintree, in October 1989. Their summary says they described a previously unreported test. Wrong! Dr M.E. Lee from Rambam Medical Center, Haifa, Israel, described this test in a letter to Anaesthesia in 1988 (*Anaesthesia* 1988; **43:** 705–6). I call it the Israel Test, for obvious reasons, but prefer 'Whoosh', as it is so descriptive. I have now used the test in well over 1000 cases, and find it 100% reliable, and never resorted to epidurogram for confirmation, except on one occasion when the radiologist asked me to do a diagnostic epidurogram. This showed the dye in the epidural space, and air superior to it (positive Woosh).

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Pre-operative removal of dentures

Authors of the recent correspondence on 'Pre-operative removal of dentures', may be interested in the following quote from a popular anaesthetic text written in 1929 [1]. 'A complete upper denture is very unlikely to give rise to any difficulty, but the smaller the fitting the greater the potential danger. A woman patient sometimes becomes so agitated at the idea of being seen without teeth that it may be easier to allow them to remain until she is unconscious and remove them then.'

It seems that these authors, both eminent anaesthetists of their time, would have little quarrel with D.V. Thomas' views (*Anaesthesia* 1991; **46:** 1094) but in this case, how and when did the fashion for compulsory removal start?

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Reference

[1] ROOD FS, WEBBER HN. *Anaesthesia and anaesthetics*, London: Cassell and Company, 1929.

Anaesthesia, 1992, Volume 47, pages 453–455

Book reviews

Recent advances in anaesthesia and analgesia 453
Edited by R.S. ATKINSON AND A.P. ADAMS
Pharmacokinetics for anaesthesia 453
C.J. HULL
The pediatric anesthesia handbook 454
Edited by C. BELL, C.W. HUGHES AND T.H. OH
Anaesthesia, analgesia and intensive care 454
Edited by A.P. ADAMS AND J.N. CASHMAN
Conduction blockade for postoperative analgesia 455
Edited by J.H. MCCLURE AND J.A.W. WILDSMITH

Recent advances in anaesthesia and analgesia

Edited by R.S. ATKINSON AND A.P. ADAMS. Pp. ix+202. Churchill Livingstone, 1992. £19.95.

It is 3 years since the 16th volume of *Recent advances in anaesthesia and analgesia* was published and the same editors have produced another excellent edition. Patient safety, the theme of the book, is introduced comprehensively by one of the editors. Standards of monitoring, machine checks and product liability, of training, education and competence are related to international and national practice and the role of the Anaesthesia Patient Safety Foundation commended. Audit can help to identify human error and maintain safe practice, but the real difficulties faced are seen to be in funding and establishing recognition that only professionally qualified anaesthetists should practice unsupervised.

An American team present the evolution of the new specialty of trauma anaesthesia. Helicopters raise you from the basic Level III trauma centre to Level II or I which treats 600 cases or more annually. Road accidents are twice as common in the USA than in the UK and perhaps after trauma the patient is safer in the helicopter. Strict resuscitation protocols are stated. The initial description of the resuscitation of traumatic shock resembles peri-operative preparations made to combat surgical trauma in our own operating theatre, but the progression to hypertonic saline and intra-osseous infusions, especially for children, is not based on the authors' own published experience. This is a thought-provoking chapter. A 'key point' that many aspects of the American trauma system could be exported successfully to the UK makes one hope that the level of trauma is not exported as well.

The chapter on anaesthesia for the repair of abdominal aortic aneurysms is a well balanced review of risk identification, peri-operative techniques and the modification of changes associated with aortic clamping. Airway catastrophes predominate in many series of anaesthetic deaths. A simple clinical test is needed to recognise cases of difficult intubation, but the only help suggested is a classification based on the visibility of oropharyngeal structures. Detection of oesophageal intubation and manipulations of the airway required for training in fibreoptic intubation are clearly stated. The chapter on acute arrhythmias concludes with the statement that some understanding of basic electrophysiology is extremely helpful. If this hint came at the beginning, the wealth of information contained in this short chapter may be more accessible.

Postoperative hypoxaemia is briefly reviewed and at times is repetitive. Physiological symbols are not presented accurately. Recent advances in postoperative pain relief follows the safety theme of the volume. Physiology, pharmacology, techniques, clinical management and comparisons of risk are succinctly presented and the argument builds up to the need for a specialist in pain relief to be responsible for an acute pain service. The parting comment is that if the surgeons do not demand aggressive analgesia with minimal risks, consumers should.

Management of severe pre-eclampsia covers the use of magnesium sulphate which may not be a familiar agent in UK practice. More familiar may be antagonists which allow other drugs to be reversed safely or they may have themselves a potential for serious complications. The clinical significance of the side effects of benzodiazepine and opioid antagonists is discussed. Severity scoring is explained in the final chapter which ends with a series of questions, one of which is: at what point in a patient's illness can we be certain about the outcome? Perhaps mathematicians with a knowledge of chaos theory should answer this. A reply is suggested—that such systems are not substitutes for clinical judgement.

There is no doubt that by reading this book the clinical judgement of any anaesthetist will be improved. It should be read and discussed by every anaesthetist.

A. HOLDCROFT

Pharmacokinetics for anaesthesia

C.J. HULL. Pp. xiv+421. Butterworth, Heinemann, 1991. £60.00

The author of this truly remarkable book told a number of individuals about it during its gestation and indicated that it would be just right for us, that is, those who acknowledge their bafflement with pharmacokinetics. The question now is, was he correct in his forecast? One can certainly 'hear' him as one reads, particularly in the enthusiastic and polemic parts; his individual emphases and phrases which appear naturally serve to reinforce the fact that this is a single-author book.

There are five sections which lead on from one another in a logical fashion. 'Basic essentials' is quite a demanding section, to the extent that it will cause the fainthearted to falter. It consists of a revision of some essential mathematics and molecular activity in relation to drugs together with a few of the strange terms which pharmacokineticists use. The subject of the fates of drugs in the body is closer to everyone's understanding and does not pose too many problems. Both these sections are clear and relatively straightforward.

'Pharmacokinetic analysis' is strong stuff indeed, and multicompartmental analysis involves some pretty advanced mathematics. It is perhaps worth reiteration to state that, whatever difficulties an individual reader may encounter, persistence will be rewarded with an improved understanding of the subject. Meanwhile, the author tries to be 'on the reader's side' and to encourage comprehension of the complexities of algebra and differential equations by a number of devices (models, graphs, clinical examples, homely illustrations and a few jokes). He succeeds in this more often than not but sometimes may appear to be guilty of a little condescension. Many of the chapters are quite short so fatigue is discouraged.

The section on pharmacokinetics of some anaesthetic drugs is really an extended and critical review of a large number of articles. Each group of drugs is considered in relation to what is published about their pharmacokinetics and well known effects are explained in kinetic terms. Inhalational, intravenous, opioid and neuromuscular drugs are considered in separate chapters. This is a very interesting section of the book and the ease of reference to the more basic descriptions is convenient.

The final section, 'putting pharmacokinetics to work', is the end-point of the entire exercise: the application of pharmacokinetics to the design of programs and operation of computers to control analgesia and muscular relaxation during anaesthesia. Hull emphasises the requirement to accept pragmatically the equations on which the designs are based and then to test their validity rigourously. One such program, Project, (for an extra £30) 'accompanies' the book and it is claimed that simultaneous use of both would be rewarding. My experience with the program is limited to a few attempts which were not very informative: the requirement to tell the computer, for example, the target concentration of a drug presumed that the therapeutic level was already known! However, the computer did demonstrate how the blood level would change in response to what one believed to be a reasonable dose of drug; but not yet being sufficiently conversant with pharmacokinetics this user remains a little sceptical about the value of this facility.

Some years ago I tried to understand this topic but I was hindered at the start of my endeavours because so much of the basic physicochemistry was described in relation to drugs which were not at all familiar: the search for information, for example about pH and pKa of some anaesthetic drugs, was so frustrating that this quest for knowledge was abandoned. There would be no such flimsy excuse for such sloth now. This book is not for an idle read; it is a textbook for study and for reference: as such it amply rewards the diligent.

J.N. LUNN

The pediatric anesthesia handbook

Edited by C. BELL, C.W. HUGHES AND T.H. OH. Pp. 626. Mosby Year Book Publishers, 1991. £34.95.

This spiral bound paperback handbook has been written by the team that developed the Yale Paediatric teaching programme. It was conceived as a means to assist junior anaesthetists to assimilate quickly the necessary details of paediatric anaesthetic practice.

The book is divided into 23 chapters written by various combinations of 27 authors. Despite this multi-author contribution there is little repetition and the three editors have performed their editorial task well. There are four appendices, one of which is a 53 page drug table. The main anaesthetic techniques have been described by physiological system (e.g. anaesthesia of gastro-intestinal disorders, anaesthetic management of paediatric neurological disorders) rather than by the more usual anatomical surgical classification. Although this works overall it does lead to some strange 'bedfellows' and as a result it is difficult to find quickly reference points and to assimilate a global view of a particular surgical or anaesthetic problem. Chapters are included on pain management, equipment and monitoring, anaesthesia in remote locations and transplant surgery, all specifically orientated to the paediatric patient. Each section is well written, easy to read and its short sentence format makes learning or revision for a multiple choice question examination a simple task. Each chapter is referenced or concludes with a bibliography and some have both. Although the bibliography lists are extensive they are not selective and I found myself looking at a long list of books rather than specific items within them.

The chapters include a large quantity of basic physiology and pharmacology. Although some of this is specifically relevant to paediatric practice, the vast majority is no more than basic knowledge which could be gleaned more easily from a standard physiology or pharmacology text. The quantity of this basic knowledge included in overall terms is excessive and it would be hoped that any anaesthetist in training wishing to embark on paediatric anaesthesia would already have this wisdom.

The text sets out to provide a series of valid alternative methods of management. Unfortunately, it does not provide sufficient guidelines as to which alternative to use and why this particular choice was made. Thus at the end of a chapter I found myself saturated in basic physiology and pharmacology, instructed, albeit briefly, in various management techniques, but none the wiser as to how to actually perform a technique or deal with a particular situation.

As a handbook, I found this text disappointing. There were plenty of tables, but instead of simplifying the text, they made it more difficult to find a specific subject. Bleeding tonsils for example is dealt with in half a column of a table on common problems in the postanaesthetic recovery room. I could find little to describe how to anaesthetise a routine inguinal hernia, unbilical hernia or circumcision, probably amongst the commonest procedures encountered by most anaesthetists. There were 40 pages on anaesthesia for children with congenital heart disease, 30 pages on anaesthesia for paediatric transplant surgery but only five pages on paediatric outpatient anaesthesia. This may reflect the practice as seen by the authors and anaesthetic staff at Yale, but I doubt it, as North America is reporting 60% day care paediatric anaesthetic practice. One omission I found strange was the lack of any text on paediatric cardiopulmonary resuscitation, yet there were 30 pages on neonatal resuscitation.

I find it hard to recommend this book. It has some very good basic physiology and pharmacology and includes useful information on the more specialised paediatric anaesthetic techniques. Unfortunately, it has completely omitted routine practice and does not provide a logical guide to the problems of paediatric anaesthesia. This I consider unforgivable in a handbook of paediatric anaesthesia.

D.A. ZIDEMAN

Anaesthesia, analgesia and intensive care

Edited by A.P. ADAMS AND J.N. CASHMAN. Pp. vi+313. Edward Arnold, 1991. £14.95.

There is nothing on either cover of this book to indicate its intended readership. Thus, I awaited with anticipation the arrival of this 550 g, 313 page paperback, the back cover of which modestly claimed 'concise coverage of every aspect of the anaesthetist's required expertise'. The preface produced the first surprise. This is, in fact, an undergraduate book, written because the authors considered that the medical student 'was not comprehensively served by the existing range of textbooks'.

There are 17 authors, representing most of the Teaching Centres in London; several are experienced writers, well known in their particular fields. Nineteen chapters cover a wide range of topics which include anaesthesia, physiology, fluid, electrolyte and acid base balance, monitoring, apparatus, obstetrics, paediatrics, cardiopulmonary resuscitation, head injury, brain death, pain management and intensive care. There are 34 figures and 41 tables. Each chapter begins with a summary of its contents and further reading material is suggested at the end of most chapters. The text is well laid out, it is readable, despite the large amount of information contained within, and the material is up to date.

My initial thoughts were that the contents appeared to be greatly in excess of medical students' requirements. This impression was echoed by some of our anaesthetic trainees who leafed through the pages; significantly, however, several of them thought that there was much in it which would have been of benefit to them in their first year of anaesthetic training.

My second surprise was that the medical students to whom I showed the book, instead of being overwhelmed by its size and scope, were extremely enthusiastic about it. Particular mention was made of its readability, beautiful layout and the summary of contents at the beginning of each chapter. The physiology was considered to be sufficiently clear and self-contained that recourse to other texts was not necessary. The pharmacology chapter scored particularly well with one student, whose memory of a previous lecture on the subject had 'put her off for life'. The detailed descriptions of practical procedures were welcomed, although I thought personally that the diagrams showing tracheal intubation were not particularly clear. One student commented that, on the next visit to the operating theatre after reading the book, 'things actually started to make more sense'.

I believe that this book will serve more than one function. Several chapters are essential reading for final year students, whether or not they have any interest in anaesthetics. There is a temptation for some undergraduates to ignore specialities which do not feature prominently in examinations. However, subjects such as fluid, electrolyte and acid base balance, cardiopulmonary resuscitation, respiratory assessment, oxygen therapy, postoperative pain relief, practical procedures and the indications for intensive care are essential to the undergraduate curriculum, since they form the basis of their first year in hospital practice. The teaching of these subjects should certainly be given priority over many of the more esoteric aspects of medicine with which the student is often regaled. This book should be read by all doctors contemplating a career in anaesthetics, and trainees in their first year will find much of interest. I also think that, from time to time, it should be read by anaesthetists involved in the training of a new senior house officers. For those consultants who feel themselves becoming stale and repetitive, this book will serve as a useful framework for initial teaching, as a reminder of the scope of anaesthetic practice and a means of answering some of the awkward questions posed by beginners.

Undoubtedly, this book brings to life both anaesthesia and the practical aspects of acute medicine. It should be compulsory reading for all medical students.

R. Mason

Conduction blockade for postoperative analgesia

Edited by J.H. McClure and J.A.W. Wildsmith. Pp. xiv + 230. Edward Arnold, 1991. £24.50.

The report of the joint working party of the College of Anaesthetists and the Royal College of Surgeons on Pain after Surgery made many suggestions on how to improve postoperative pain management. Included amongst the recommendations was encouragement for the increased use of local anaesthetic techniques to provide continuing analgesia into the postoperative period. The problem is knowing which block should be used for a particular operation and how to manage it. Scanning the section of the library dealing with local anaesthesia one encounters many excellent books on regional block techniques, but when one seeks information as to how such described blocks might be used in the postoperative period, sadly, there is very little guidance. Thus it was with interest and anticipation that this book was received.

On first opening the book and quickly browsing through the pages one begins to wonder where the diagrams are; surely a book on conduction blockade must have illustrated descriptions of how to perform all the various nerve blocks that might be of use! However, it soon becomes apparent that this is not the case in this volume as its objective is to concentrate more on the theoretical rather than practical aspects of the subject and therefore might be better entitled 'Mechanisms of Conduction Blockade with Reference to Postoperative Analgesia'. Thus, with a degree of disappointment at not having found the practical Holy Grail your reviewer settled down to give the book a closer look.

The first third of the text, dealing with the physiology of pain transmission and the action of local anaesthetics, is a very full and well written review of current knowledge and is the equal of, and considerably more readable than, many standard textbooks on the subject. The middle third concentrates on spinal and epidural opioids and local anaesthetics; the aspects covered being both of theoretical and clinical value. There are excellent chapters on the spread of drugs in the neuro-axis and the mechanism of action and the use of spinal opioids, the latter containing sound practical advice on their use in clinical practice. It is not until p. 175 that one encounters information on peripheral nerve blocks that might be off value in the postoperative period, but sadly such descriptions often lack diagrams which when dealing with such techniques are so important in clarifying details of landmarks, needle insertion points and angle of approach.

Overall, despite early disappointment over the content, your reviewer enjoyed reading this book and felt that as a text on local anaesthesia it had much to offer in some of its excellent chapters but, if one is looking for a 'do-it-yourself' guide to local anaesthetic blocks for the postoperative period, this may not satisfy the appetite. As a 'carry with you' aid this book misses the target but by condensing together so much current information in such a small manageable size, it should be of interest to all anaesthetists and of particular value to those studying for their Fellowship.

M. Harmer

Anaesthesia, 1992, Volume 47, page 456

Hazard Notice

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